AD-A086 462 NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA F/G 8/1
TRIDENT BIOLOGICAL SURVEYS: SUBASE BANGOR (JULY 1977 AND JUNE 1--ETC(U)
DEC 79 H W GOFORTH, T J PEELING, M H SALAZAR
UNCLASSIFIED NOSC/TR-513 NL

1 OF 2
AD A
086462

NOSC

END
DATE
FILMED
8-80
DTIC

CONT

LEVEL II

(12)

NOSC

NOSC TR 513

Technical Report 513
(Supplement 2 to NUC TP 510)

TRIDENT BIOLOGICAL SURVEYS:
SUBASE Bangor (July 1977 and June 1978) and Indian Island Annex (January, May 1974 and June 1978)

H. W. Goforth, T. J. Peeling, M. H. Salazar and J. G. Grovhoug

December 1979

Supplemental Report: July 1977 and June 1978

Prepared for
Naval Facilities Engineering Command

Approved for public release; distribution unlimited.

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

SL GUILLE, CAPT, USN
Commander

HL BLOOD
Technical Director

ADMINISTRATIVE INFORMATION

The work reported herein was performed by members of the Marine Sciences Division (Code 513) of the Naval Ocean Systems Center. Specific surveys were accomplished at SUBASE Bangor in July 1977 and June 1978 and at Indian Island Annex during January and May 1974 and June 1978. It was supported by funds administered by the Naval Facilities Engineering Command through the Officer in Charge of Construction, Trident under work request numbers N68248-77-WR-00091 and N68248-78-WR-00044.

Reviewed by
S. Yamamoto, Head
Marine Sciences Division

Under authority of
H.O. Porter, Head
Biosciences Department

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NOSC Technical Report 513
(Supplement 2 to NUC TP 510)

2. GOVT ACCESSION NO.
AD-A086462

3. RECIPIENT'S CATALOG NUMBER

4. ~~TITLE (and Subtitle)~~
(6) TRIDENT Biological Surveys:
SUBASE Bangor (July 1977 and June 1978) and Indian Island Annex (January, May 1974 and June 1978) . Supplement 2.

5. TYPE OF REPORT & PERIOD COVERED
Supplemental Report: January and May 1974, July 1977 & June 1978

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
(10) H.W. Goforth T.J. Peeling M.H. Salazar a[redacted] J.G. Grovhoug

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Ocean Systems Center
San Diego, CA 92152

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
N68248-77-WR-00091
N68248-78-WR-00044

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Facilities Engineering Command
Washington, D.C. 22332

12. ~~REPORT DATE~~
(11) Dece[redacted]979

13. NUMBER OF PAGES
84

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(9) Technical rept.,

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. ~~DISTRIBUTION STATEMENT (of this Report)~~
Approved for public release; distribution unlimited.

(12) 87

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
(14) NOSC/TR-513

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

biological survey	Trident
marine environmental conditions	bivalve molluscs
SUBASE Bangor, Washington	marine fishes
Indian Island, Washington	eelgrass beds

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In July 1977 and June 1978, biological surveys of the Trident Submarine Support Facility, SUBASE Bangor, Washington were conducted. The primary objective was to collect selected biological data for an assessment of the marine environmental conditions during a period of facilities construction.

In January and May 1974 and June 1978, a series of biological surveys were conducted at Indian Island Annex, Washington. The objective of the first two surveys was to collect seasonal biological baseline data from which the impact of proposed pier construction could be predicted. The third survey was designed to collect biological data for monitoring environmental conditions during on-going pier construction.

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

393159

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Continued from block 20.

The major effort of these surveys was directed towards quantifying the abundance and distribution of commercially/recreationally important species of marine fishes and molluscs. Other biotic components of the ecosystem were surveyed according to their relative abundance and/or importance in the food web of other species. The general conclusion supported by the data collected from a total of eight surveys is that the marine life along the SUBASE shoreline appears to be unchanged by Trident construction. Any and all biotic fluctuations appear to be natural and are in synchronization with those observed at the off-base control stations. There have been no rare or endangered species or critical marine habitats affected by construction activities. Adverse impact has been limited to the biota physically disrupted by the mechanical process of pier construction.

The three surveys conducted at the Indian Island Annex revealed the presence of marine invertebrate species typical for that area but in very low abundance. Fish population sampled at Indian Island Annex contained species common to Admiralty Inlet without remarkable characteristics.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the active support and assistance of the following persons:

D. Morris and J. Reeves of the OICC Trident Office, for their contributions during data collection and general on-site support.

Personnel of the Explosive Ordnance Disposal Mobile Unit One, Det. 56, who provided necessary logistical support: CWO-3 A.E. Huffman, CWO-4 C. Morgan, BMCM M.W. Dahmer, AO-1 B.A. Devine, AO-1 T.G. Wick and EN-1 P. Oyer.

Mr. and Mrs. A. Anderson for permitting their private property to be used as an intertidal sampling site (station L).

Mr. and Mrs. E. Martens for permitting their private property to be used as an intertidal sampling site (station A).

R. Westly and A. Scholz of the Washington Department of Fisheries, Point Whitney Shellfish Laboratory for providing information and data on oyster spatfall for Hood Canal and Dabob Bay.

LCDR R.A. Dietz and D. Bower who performed the tedious task of data reduction and assisted with initial data analyses.

M. Platter-Rieger for her statistical analysis of historical bivalve data and for writing the chapter on optimal allocation of sampling effort.

SUMMARY

In July 1977 and June 1978, members of the Marine Sciences Division (Code 513) of the Naval Ocean Systems Center (NOSC) conducted two biological surveys of the Trident Submarine Support Facility, SUBASE Bangor, Washington. The primary objective was to collect selected biological data for an assessment of the marine environmental conditions during a period of facilities construction. The data from these surveys have been analyzed and compared with those from previous surveys and are presented in this report.

In January and May 1974 and June 1978, a series of biological surveys were conducted at Indian Island Annex, Washington for OICC Trident. The objective of the first two surveys was to collect seasonal biological baseline data from which the impact of proposed pier construction could be predicted. The third survey was designed to collect biological data for monitoring environmental conditions during on-going pier construction. The results and conclusions from these surveys are presented in a separate section of this report.

The major effort of these surveys was directed towards quantifying the abundance and distribution of commercially/recreationally important species of marine fishes and molluscs. Other biotic components of the Hood Canal ecosystem were surveyed according to their relative abundance and/or importance in the food web of other species. Detailed results and conclusions from these surveys are presented in the individual sections of this report. However, the general conclusion supported by the data collected from a total of eight surveys is that the marine life along the SUBASE shoreline appears to be unchanged by Trident construction. Any and all biotic fluctuations appear to be natural and are in synchronization with those observed at the off-base control stations. There have been no rare or endangered species, nor critical marine habitats affected by construction activities. Adverse impact has been limited to the biota physically disrupted by the mechanical process of pier construction.

Commercial clam densities, standing crop (biomass), recruitment and population distributions within the tidal zones have experienced only natural fluctuations. The total biomass of commercial clams has consistently been divided as follows: butter clams 70-90%, basket cockles 0-5%, and soft-shell clams 0-5%. A few stations are found to support high densities of juvenile clams but few adults, suggesting that the environmental conditions responsible for heavy settlement (recruitment) may be unrelated to the conditions necessary for good growth and survival. On-base stations C, E, FA and Z were found to have clam densities of commercial levels which could support a well managed program of recreational harvesting. Stations CS, G and K have consistently had clam densities which are too low and patchy to be of any recreational value except for the more resolute clam digger.

Environmental conditions at several sites along SUBASE Bangor (i.e., stations C, E, K and Z) are quite conducive to good oyster settlement, growth and survival. Exceptionally good spawning conditions occurred in 1977 in Dabob Bay and Hood Canal which allowed for spatfall (recruitment) to reach commercial densities at stations C and Z. A detailed survey of the oyster bed at station C revealed a band of adult oysters 5.7 m wide and 560 m long having an average density of 36.8 oysters/m^2. Since approximately 92% of these oysters are of harvestable size, this station could easily support a controlled harvesting program. A detailed survey of the oyster bed at station Z will be conducted during survey IX (1979).

Byssal thread production tests with the bay mussel conducted in 1975, 1976, and 1977 found no differences among any of the survey stations before or during facilities construction and dredging. The summer rate of byssal thread production in Hood Canal, however, is approximately 50% higher than the summer rate in San Diego Bay and approximately 100% higher than the winter rate.

Marine fish collections during survey VII (1977) revealed a decline in both species composition and abundance compared with survey VI (1976). However collections during survey VIII (1978) revealed a complete return to the levels found in survey VI (1976). Fish collections in 1978 indicate a diverse species composition (20 species) and a relative abundance (428 individuals) that is consistent with reports of similar areas in Puget Sound. Stomach contents were typical for these species and revealed a diverse diet consistent with unstressed environmental conditions.

Eelgrass beds occurring along the Hood Canal shoreline showed large variations in standing crop (biomass) and turion (blade) density between and within stations, and between years. However, values for these measurements at stations A, E, G, K and L were average or slightly above average compared to other areas of Puget Sound.

Station FA supports only a small eelgrass bed and has a less than average turion density in the shallow portion of the bed. Stations E, K and L showed extremely large fluctuations in standing crop and density values, apparently a result of their greater exposure to natural siltation and erosion forces.

The three surveys conducted at the Indian Island Annex revealed the presence of marine invertebrate species typical for that area, but in very low abundance. Station I-B was found to be unsuitable for clams with a total of four non-commercial individuals collected during three surveys. Clam populations at station I-C were also depauperate and lower than any of the survey stations in Hood Canal. Subtidal geoduck and horseneck clams at station I-C were found to be low ($< 0.06/0.1\ m^2$) and comparable with values reported by Washington Department of Fisheries for central Puget Sound and Kilisut Spit. A substantial eelgrass bed is present at station I-C which is of average density and above average biomass. Any permanent loss of eelgrass as a result of pier construction at this station should be confined to the immediate vicinity of the pier. Fish populations sampled at Indian Island Annex contained species common to Admiralty Inlet without remarkable characteristics. Stomach contents contained food items typical for each species and representative of an unstressed environment. A cumulative species list for Indian Island Annex which contains many species common to Hood Canal is presented in Appendix D.

CONTENTS

INTRODUCTION

In 1973, the Naval Facilities Engineering Command requested that the Naval Ocean Systems Center (then the Naval Undersea Center) conduct a series of biological surveys at the proposed Trident Submarine Support Facility at the Bangor Annex of the Keyport Naval Torpedo Station, Washington, now called the Naval Submarine Base Bangor (SUBASE Bangor). Four seasonal surveys were conducted to provide baseline biological data for assessing the effects of construction upon commercially and recreationally important populations of molluscs and fishes. Other forms of marine life which play important roles in the ecosystem were also surveyed to determine their general status and relative abundance. The first four surveys were conducted in June and October 1973, and January and April-May 1974; Trident surveys I-IV, respectively. A fifth survey (V) was conducted in July 1975 at the request of the officer-in-charge-of-construction for the Trident Facility (OICC Trident). The results of surveys I-V were documented in Naval Undersea Center Technical Publication 510 (Peeling and Goforth, 1975), and in field data reports submitted to OICC Trident.

In July 1976, a sixth survey (VI) was conducted shortly after waterfront construction for the explosives-handling wharf (EHW) and piling stress testing near Devil's Hole had begun. This survey was designed to assess the effects of construction upon marine life at SUBASE Bangor by comparing new data with those collected during surveys I-V. The results of survey VI were published as Supplement 1 to Naval Undersea Center Technical Publication 510 (Peeling et al., 1976).

In July 1977, a seventh survey (VII) was conducted to monitor the effects of a variety of on-going Trident construction projects upon the Bangor marine life. The results of this survey were analyzed and compared with the previous six Trident surveys. No formal report was published at that time, therefore the results and conclusions of survey VII are included in this report.

In June 1978, an eighth survey (VIII) was conducted to evaluate the effects of previous Trident construction projects. Since the majority of shoreline construction was completed, the data from this survey provided a basis for a final evaluation of the impact of Trident construction upon the marine life of SUBASE Bangor. The data from survey VIII were also used to critically evaluate the survey methods and procedures used over the past years to monitor the effects of shoreline construction. This evaluation has produced several recommendations for improving the survey design and optimizing the survey efforts. The purpose of this evaluation was to recommend procedures for effectively monitoring the marine environment at SUBASE Bangor in the future as it converts into an operational Trident submarine base.

Three short-term biological assessment surveys were conducted at Indian Island Annex, Washington in 1974 and 1978 in conjunction with Trident surveys III, IV, and VIII. The purpose of the first two surveys was to acquire biological baseline data to assess the effects of proposed pier construction. The third survey was designed to collect biological data to monitor the effects of on-going pier construction. The results of the first two surveys were originally analyzed and published as a field data report and submitted to OICC Trident in 1974. The data from the third survey have been combined with those from the first two surveys and are presented as a separate section of the present report.

Trident surveys VII and VIII followed the same procedures and methods as survey VI. The same species of marine organisms were studied and survey stations were the same (except for the inclusion of stations CS and FA in survey VII). Maps of SUBASE Bangor and Indian Island Annex (Figs. 1 and 16) show the locations of all survey stations.

Station descriptions, a cumulative checklist of marine organisms identified for SUBASE Bangor, and a complete list of references have been previously reported (Peeling and Goforth, 1975). This report includes the checklist of marine organisms identified for Indian Island and additions to the lists mentioned above.

BIVALVE MOLLUSCS OF SUBASE BANGOR

Bivalve molluscs are relatively immobile filter-feeding organisms that remain in a given area during their entire life span. As a result, they are constantly exposed to and influenced by the environmental conditions of that area. Bivalve molluscs dominate the biomass of the intertidal zone and are of major recreational and commercial value in the Puget Sound area. The effects of environmental perturbations upon bivalve populations have been the subject of several studies: basket cockles (Ratti, 1977); butter clams (Nickerson, 1977); mussels (Salazar, 1974; Van Winkle, 1970); native littleneck clams (Paul and Feder, 1973); oysters (Butler, 1965; Westley, 1964); and Japanese littleneck clams (Ohba, 1959). A study of the environmental impact of red tides (Simon and Dauer, 1977) suggests that mullusc (and amphipod) population data are useful in detecting the displacement of a benthic community away from its "equilibrium" condition.

This section presents data on the ecology, distribution, and density of the following species of bivalves: The basket cockle *(Clinocardium nuttalli)*, the native littleneck clam *(Protothaca staminea)*, the butter clam *(Saxidomus giganteus)*, the Japanese or Manila littleneck clam *(Tapes* japonica)*, two soft-shell clams *(Mya arenaria* and *M. truncata)*, the Pacific oyster *(Crassostrea gigas)*, and the bay mussel *(Mytilus edulis)*.

INTERTIDAL CLAMS OF COMMERCIAL AND RECREATIONAL IMPORTANCE

Introduction

The bivalves discussed in this section are considered to be commercially and/or recreationally important and therefore represent a valuable marine resource. Commercial harvesting of clams and oysters does not occur along the SUBASE Bangor shoreline; however a significant number of sport clam diggers make substantial collections during extreme low tides. Because of the recreational value of the clam and oyster populations along SUBASE Bangor, the Navy strictly regulates and monitors bivalve harvesting.

A number of environmental factors affect the growth, abundance, and distribution of intertidal clams within given geographic areas and intertidal zones. Several important factors for Northwest Pacific clams have been previously reported: tidal height (Nickerson, 1977; Ratti, 1978; Goodwin, 1973; Paul and Feder, 1973); substrate (Goodwin, 1973; Nosho and Chew, 1971; Swan 1952); and temperature (Pearce, 1965; Bourne and Smith, 1972; Goodwin, 1974; Mann and Glomb, 1978).

Growth and recruitment studies of the Japanese littleneck clams in Hood Canal have been reported by Holland and Chew (1974) and Nosho and Chew (1971). Data from these studies provide a basis for comparisons with Trident survey data. An extensive 3½-year study of a Japanese littleneck clam population (Ohba, 1959) revealed that unless

---

* *Tapes japonica* (Deshayes, 1853) had been referred to by junior synonyms of *Venerupis japonica*, *V. philippinarum*, *V. semideccusata* and *Tapes semideccusata* (Mann and Glomb, 1978).

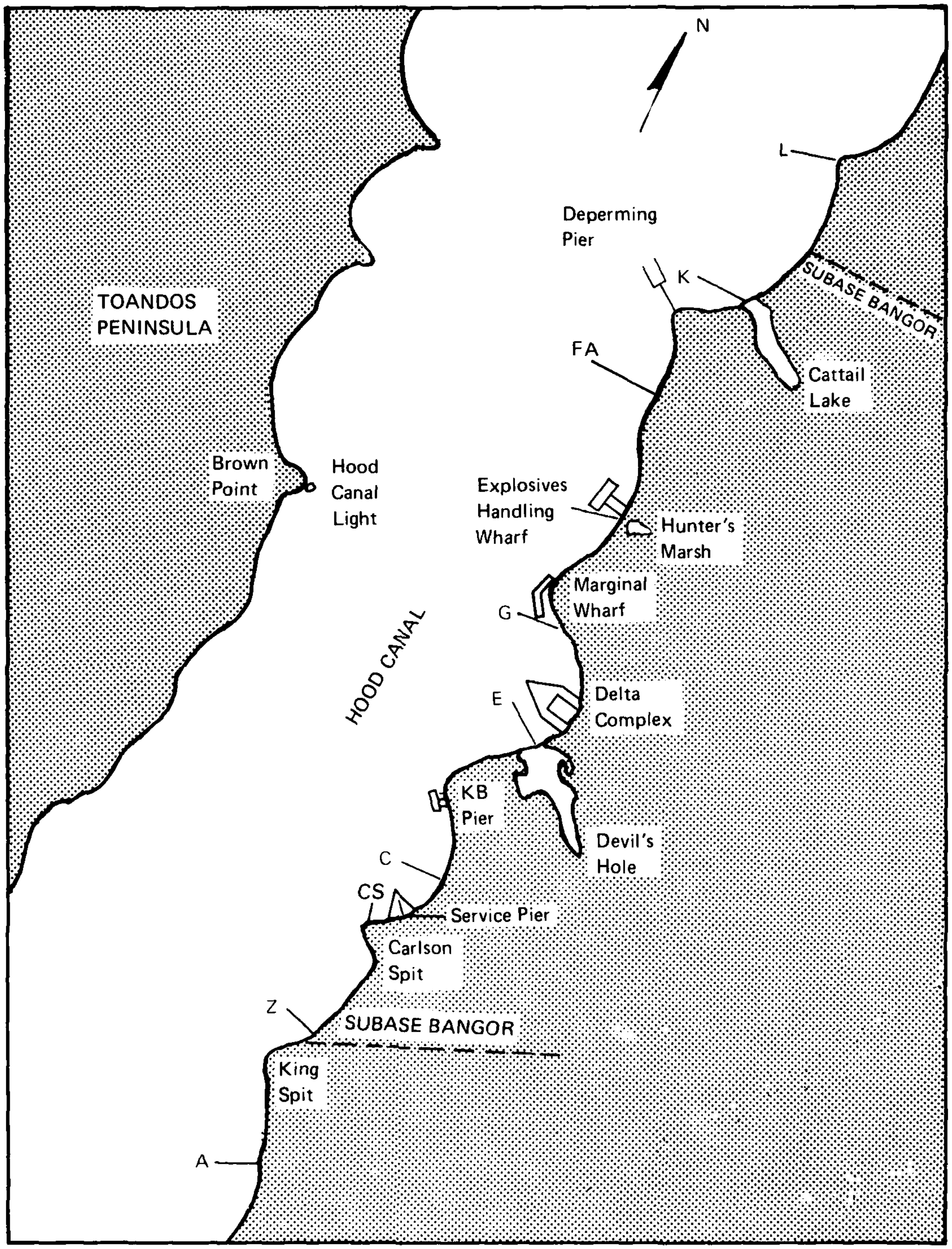

Figure 1. Map of SUBASE Bangor showing location of biological sampling stations.

unusual variations in environmental conditions occurred, clam biomass and density values follow highly regular seasonal cycles that repeat yearly with slight variations in phase and degree.

Materials and Methods

Intertidal digs were made at stations A, C, CS, E, FA, G, K, L, and Z in 1977 and again in 1978, with the exception of CS and FA. Digs were made along a transect line extending across the intertidal region between the low tide level and the extreme high tide level.* Tidal heights were determined with a technique employing two wooden poles approximately 1½ m long, one of which was marked at 0.125-in (3-mm) intervals (Emery, 1961). The poles are held vertically at measured intervals along the transect line. Differences in elevation were then determined by aligning a sighting level on the calibrated pole with the top of the second pole. The distance between the poles was 1½ m on steeper slopes and 5 m on gradual slopes. The initial measurement was made at the waters' edge at the exact time of low tide (this point was assigned the tidal height listed in the appropriate tidal table) and served as the benchmark for determining all other tidal heights at a given station. Variations in tidal profiles between years is probably due to the inability of the tide tables to account for all the meteorological conditions which influence the magnitude and time of the tidal stages.

A minimum of one dig was made in each major intertidal zone for biological sampling. Replicate digs were made in selected zones to determine the upper intertidal limit of commercial clam species and to develop representative density profiles. As in the previous surveys, a 0.1-m^2 quadrat was pushed into the substrate to delineate the area of the dig and to prevent sidewall collapse. All material to a depth of approximately 45 cm was removed and placed in a large cylindrical "washtub" (1 by 1 m) with three sorting screens and no bottom. The first screen (18-mm mesh) retained the largest clams, the second screen (6-mm mesh) most of the intermediate clams, and the third screen (2-mm mesh) the smallest clams. The third screen was required to quantify the recruitment of juvenile clams at the various stations. All clams were identified to species, measured, and counted. Commercial clams of harvestable size ($\geq$ 30 mm) were weighed on a triple beam balance to determine biomass. If a dig contained $\geq$ 277 g/0.1 m^2 (i.e., 0.5 lb/ft^2) of commercial clams it was considered of commercial value (Washington State Shellfish Laboratory, personal communication, 1975).

The density of commercial clams for each species was determined for each station by totaling the number of clams of commercial size and dividing by the area sampled.

$$\text{Density of Species A} = \frac{\Sigma \text{ Species A individuals} \geq 30 \text{ mm}}{(\text{\# digs containing commercial clam species})\ (0.1\ m^2)}$$

These data were normalized by calculating the densities only from digs containing commercial clam species. Total biomass was determined for each station and species, and the data reported as mean biomass in kilograms per square meter for comparative purposes. The upper intertidal limit for commercial species was determined by random digs at each

* The time of surveys VII and VIII, like that of surveys I-VI, was chosen to coincide with the lowest tides of the sampling month.

station. In addition, the total number of clams in the commercial (i.e., $\geqslant$ 30 mm) and subcommercial (i.e., $\leqslant$ 30 mm) size ranges was calculated for each species, dig site, and station. The subcommercial group was further subdivided by counting the number of clams 10 mm or smaller in length. This group was comprised of individuals that settled out from the plankton since last year's survey. With these data, the distribution and abundance of clams by species and size can be compared for each station.

Results and Discussion

The relative position and number of digs at each station are shown in Figs. 2 through 10. The tidal height profiles in these figures represent the actual terrain at the sampling stations. These figures provide a means of determining the tidal height for any given point along the transect line (vertical lines delineate substrate zones). Random digs were made at each station to locate the upper tidal limits of the four dominant commercial bivalve species. The results of these digs are presented in Table 1.

	Station								
	A	C	CS	E	FA	G	K	L	Z
Basket cockle	-1.2	NP	-2.0	NP	NP	+1.7	0.0	0.0	NP
Butter clam	+2.0	+5.0	0.0	+1.0	+1.5	+1.7	+5.1	+3.1	+3.4
Native littleneck clam	+4.4	+5.4	+2.0	+2.8	+1.5	+2.2	+5.1	+3.1	+5.5
Japanese littleneck clam	NP	+5.4	NP	+2.8	NP	NP	+3.2	+3.1	+5.2

NP = not present

Table 1. Upper tidal limits (ft) for commercial clams at SUBASE Bangor sampling stations.

Table 2 presents a comparison of the average combined biomass (kg/m^2) of commercial clam species at the Bangor stations:

	Station								
	A	C	CS	E	FA	G	K	L	Z
1977	5.88	10.43	1.97	4.71	7.08	4.00	0.51	6.13	5.74
1978	9.88	10.77	NS	6.30	NS	2.36	0.50	NC	3.39

NC = no commercial size clams
NS = not sampled

Table 2. Average commercial clam biomass for SUBASE Bangor sampling stations (1977 and 1978).

The clam biomass and abundance data from the 1977 and 1978 surveys are discussed below. The relative and absolute biomass/abundance of clams is described for each sampling station.

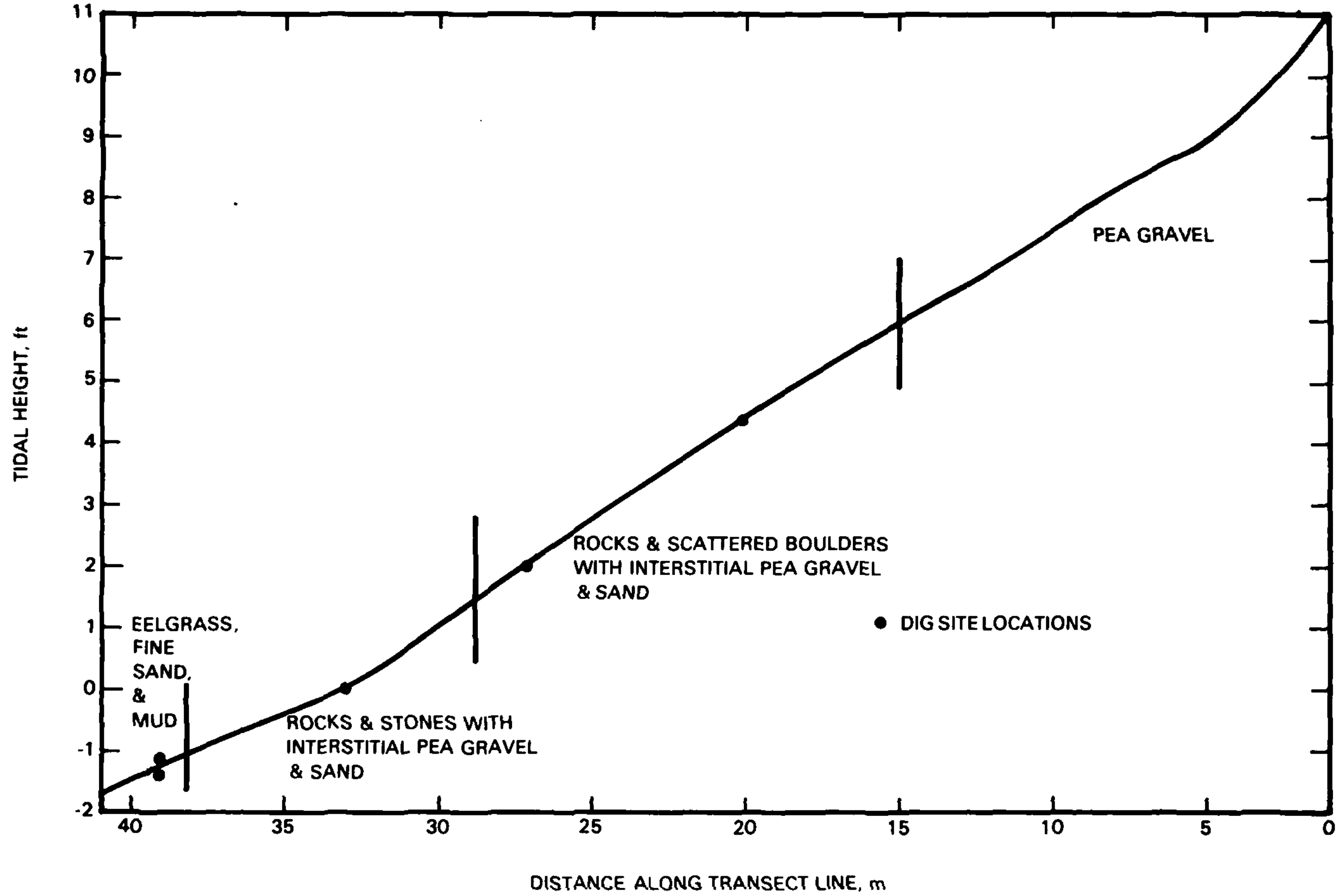

Figure 2. Beach profile at station A and dig site locations.

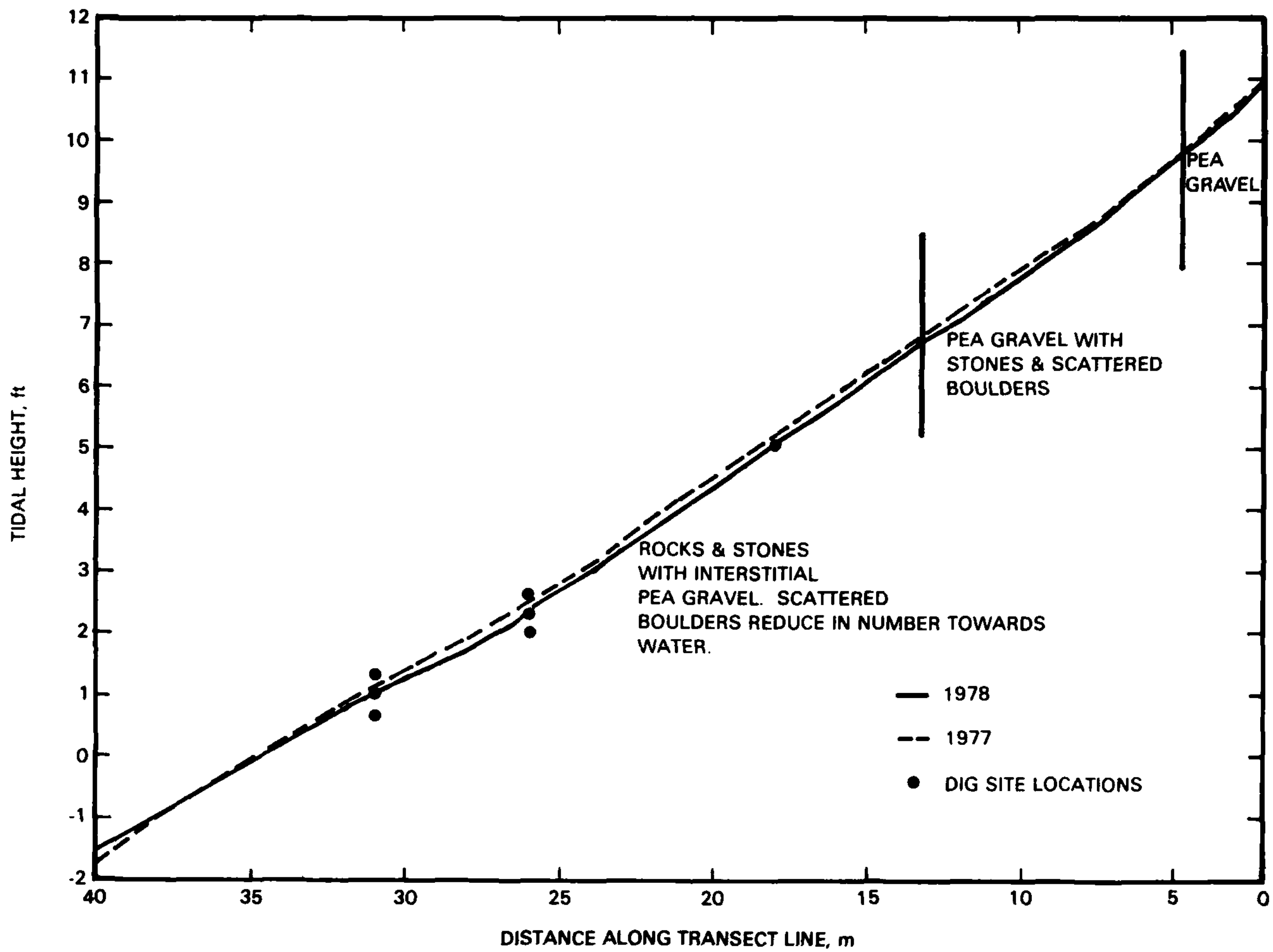

Figure 3. Beach profile at station C for 1977 and 1978 and dig site locations.

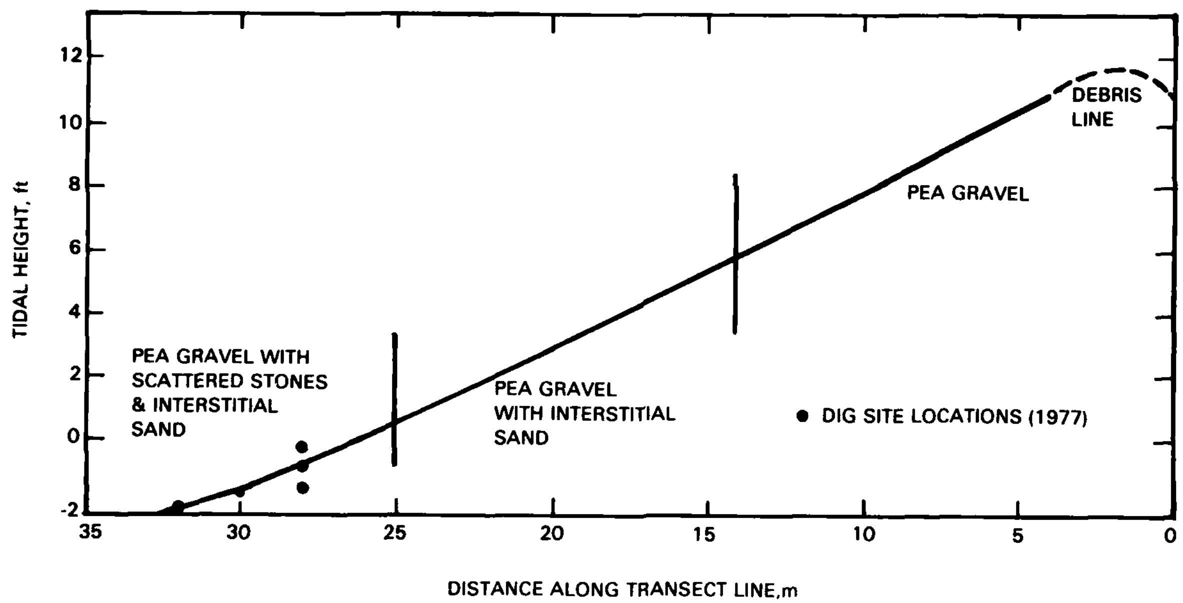

Figure 4. Beach profile at station CS and dig site locations for 1977.

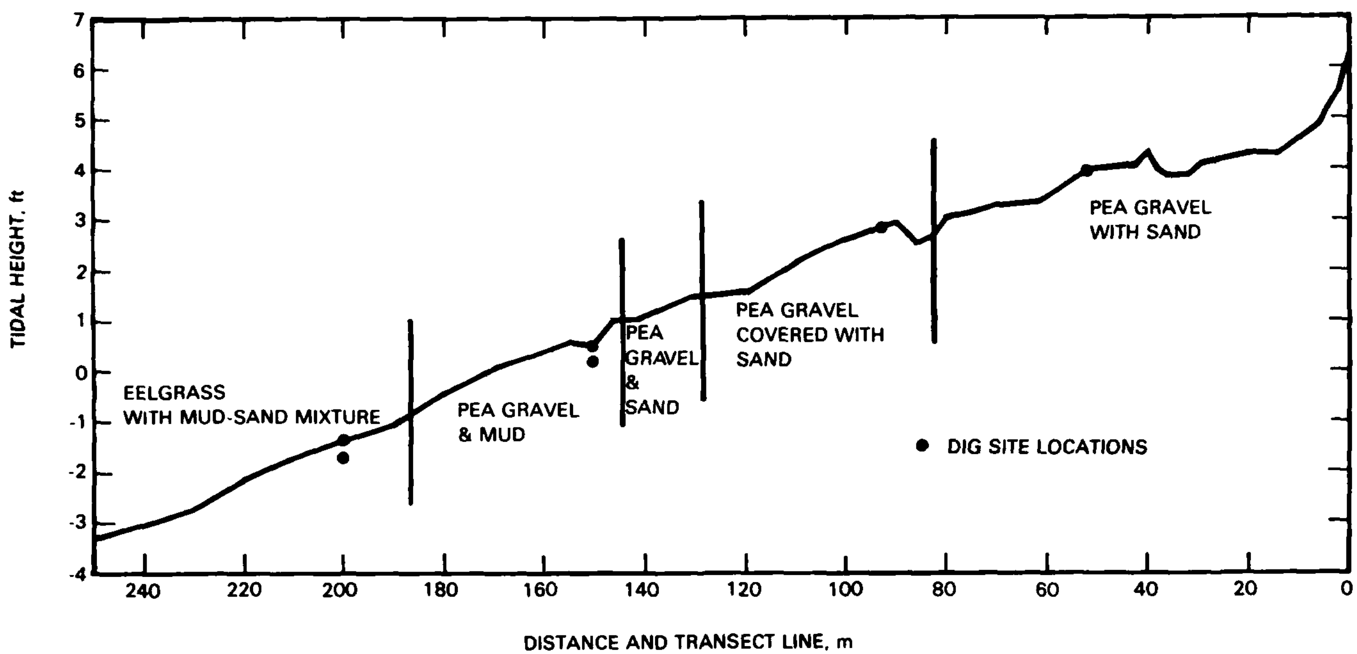

Figure 5. Beach profile at station E and dig site locations.

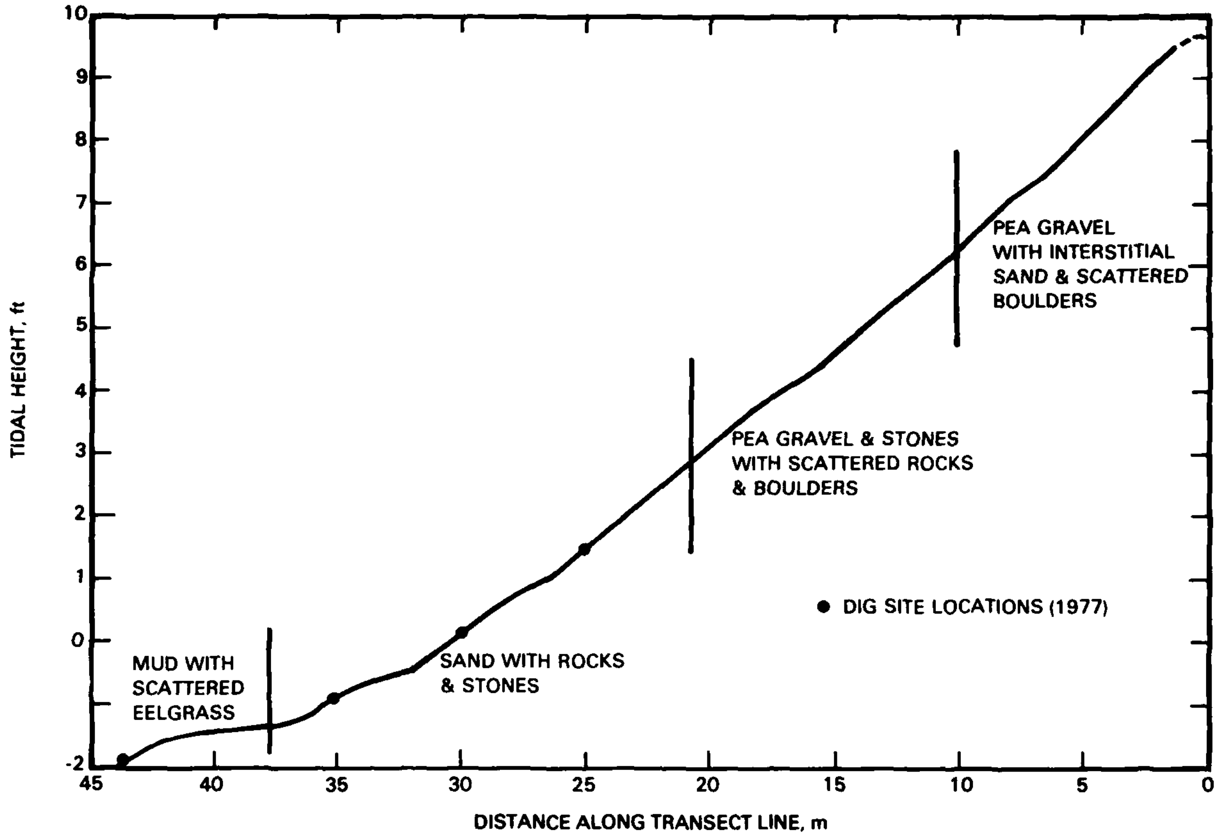

Figure 6. Beach profile at station FA and dig site locations.

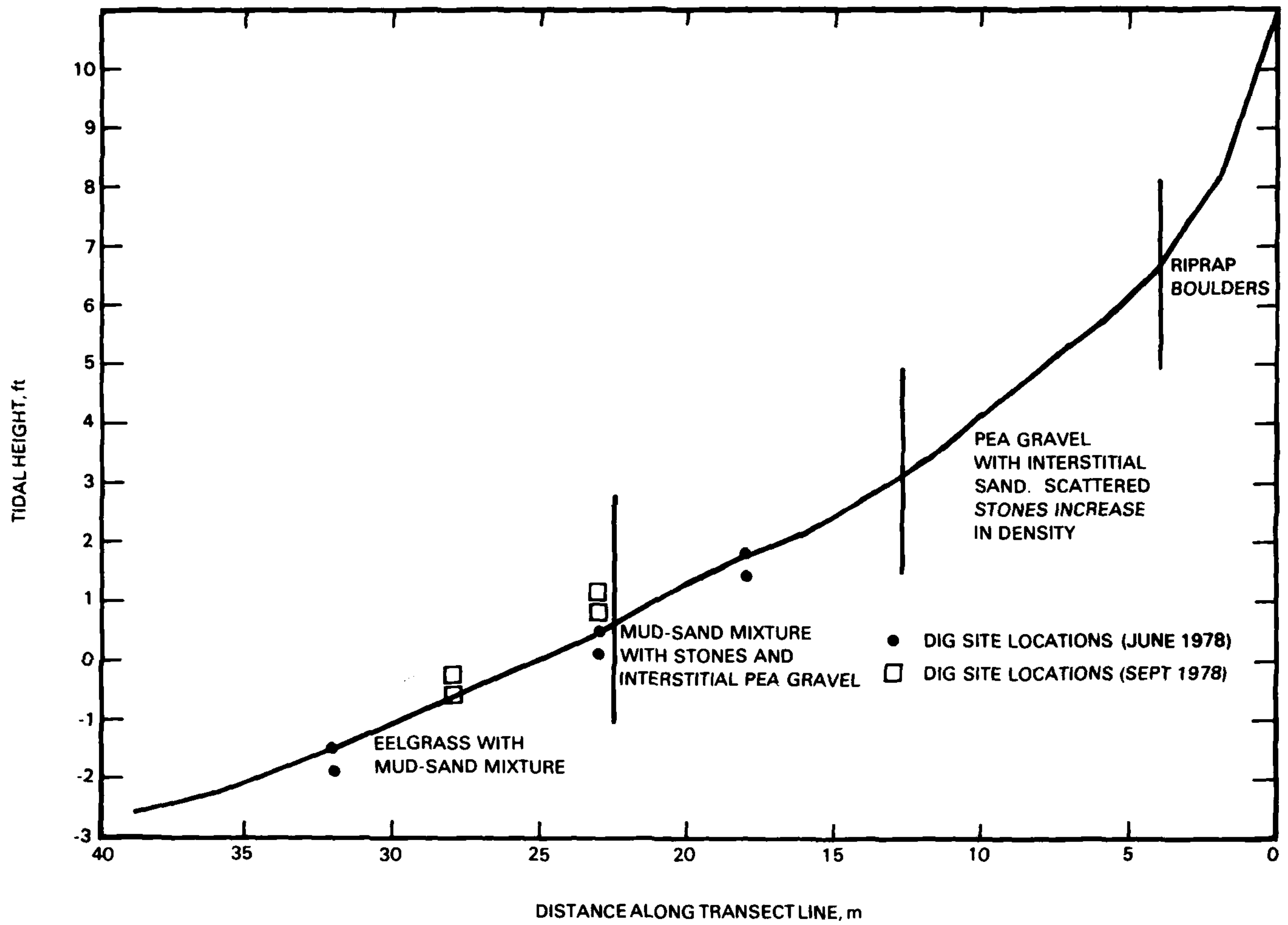

Figure 7. Beach profile at station G and dig site locations.

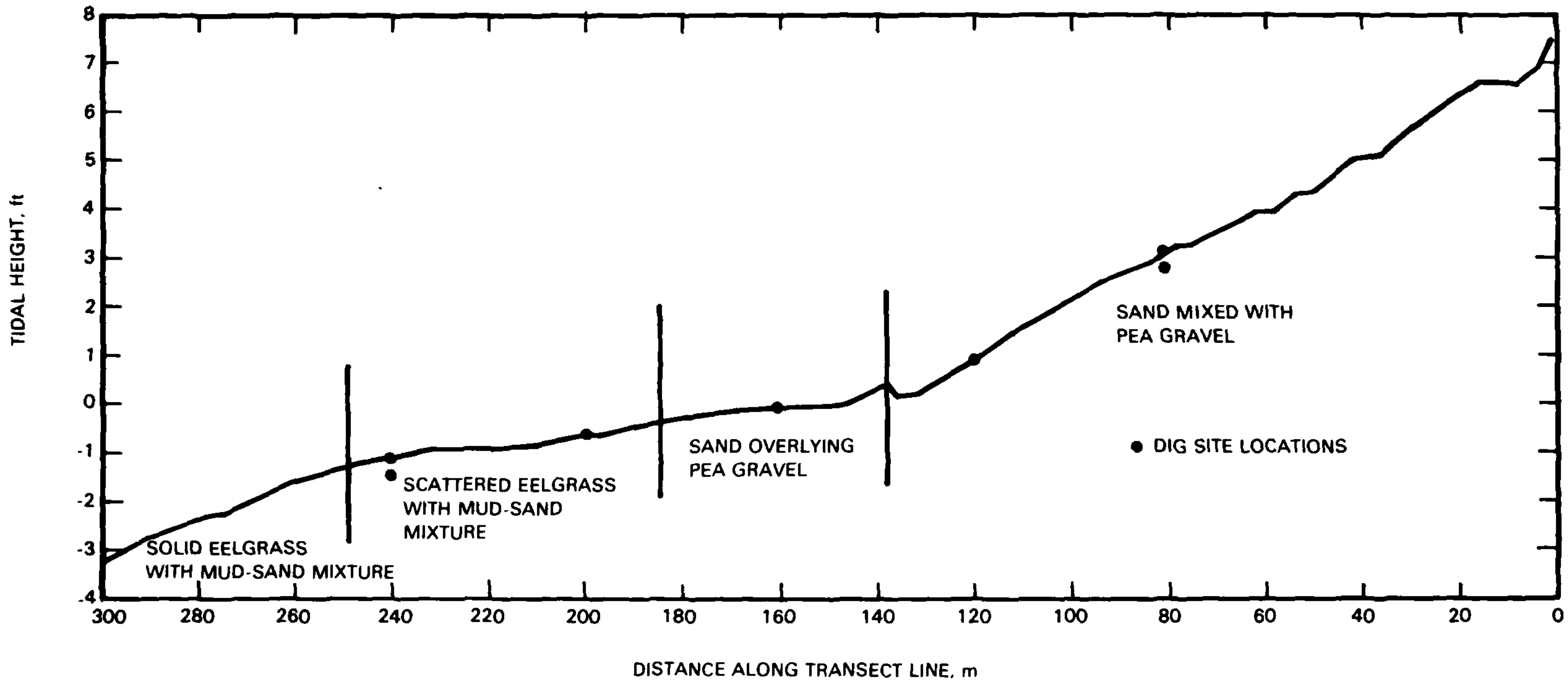

Figure 8. Beach profile at station K and dig site locations.

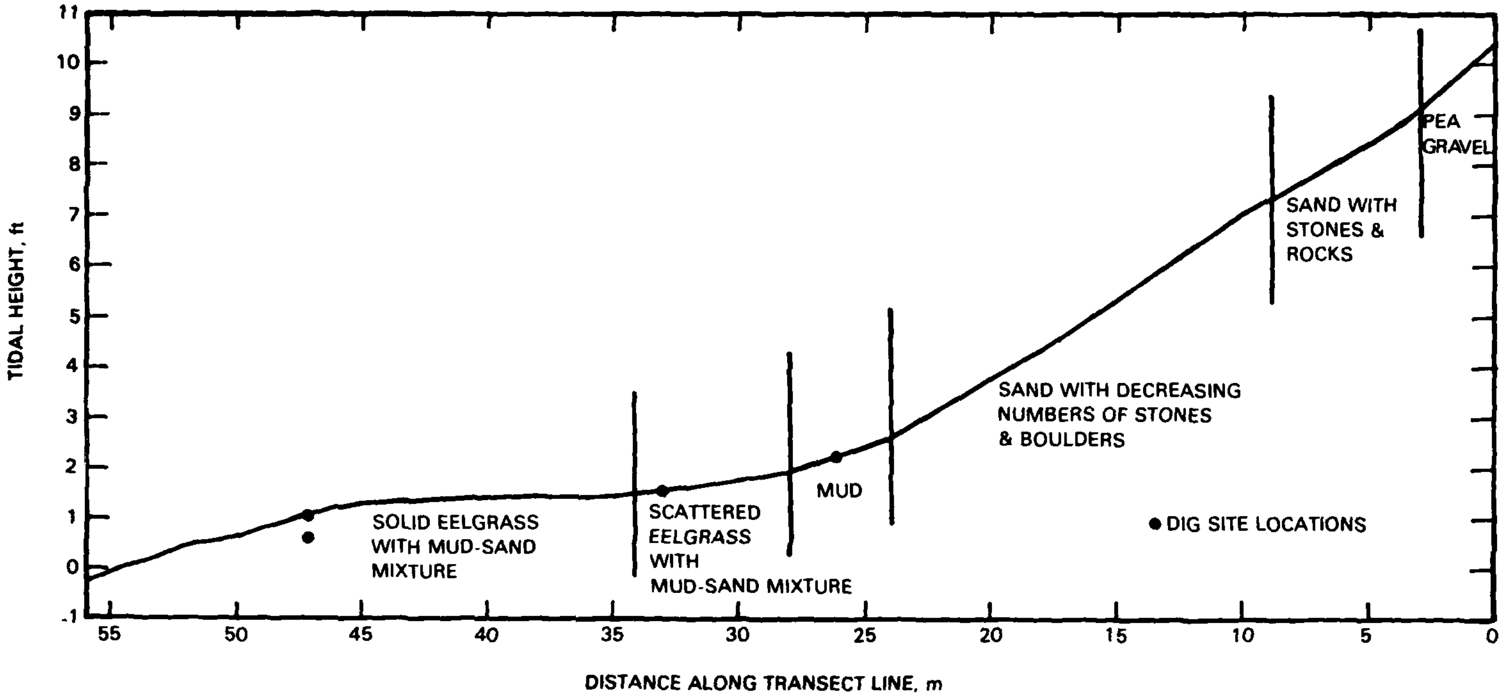

Figure 9. Beach profile at station L and dig site locations.

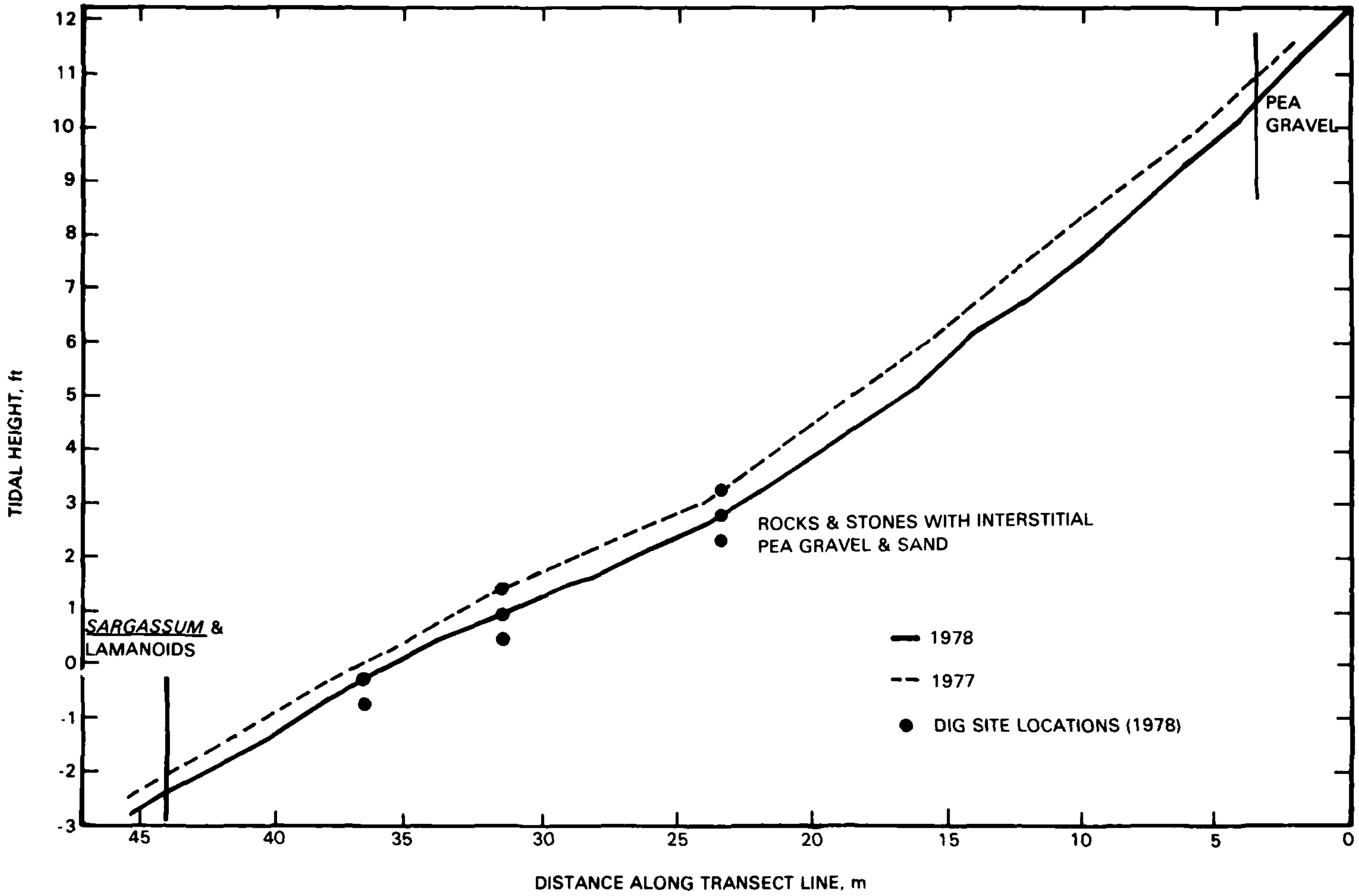

Figure 10. Beach profile at station Z for 1977 and 1978, and dig site locations.

STATION A

Intertidal digs were made at this off-base control station between +4.4 and −1.5 ft to determine the commercial clam density, biomass, and tidal limits. No commercial clams were found above +2.0 ft, except one juvenile native littleneck at +4.4 ft, which in all probability will not survive the winter stress. No Japanese littleneck or soft-shell clams were present, and no commercial size basket cockles were found in 1977. The average biomass of commercial clams at this station in 1977 was 5.88 kg/m^2. In 1977 butter clams accounted for 53% of the total biomass and native littlenecks 47% (Table A-1*). In 1978 the average biomass was 9.88 kg/m^2, almost double that of the previous year. In 1978 butter clams accounted for 60%, native littlenecks 30%, basket cockles and soft-shell clams both 5% of the clam biomass (Fig. 11). In 1977 and 1978 station A had the highest average biomass of native littleneck clams (i.e., 2.76 and 2.95 kg/m^2) of any station surveyed. Native littlenecks attained their maximum biomass (4.08 kg/m^2) and density (23.5/m^2) between the +1.0 and 0.0 ft tidal levels. This compares favorably with previous studies (Nickerson, 1977; Paul and Feder, 1973) that report the zone of maximum density for native littlenecks to fall between +1.0 and −1.0 ft. The commercial-size native littlenecks collected in 1977 and 1978 represented 68 and 83%, respectively, of the total for that species. In 1977 and 1978, commercial-size butter clams represented 53 and 58%, respectively, of the total for that species.

Substantial recruitment of native littlenecks occurred in 1977 with 36% being 10 mm or less in length. In contrast less than 1% of the native littlenecks were this size in 1978, indicating a year of low recruitment or high juvenile mortality. Butter clam recruitment and survival appears to have been best in 1978, with 42% of that species being 20 mm or less. By comparison, 1977 was a poor year for recruitment, with only 12% of the butter clams being 20 mm or less.

STATION C

Intertidal digs were made between +5.4 and +1.0 ft at this SUBASE Bangor station. No commercial clams were found above the +5.4-ft dig site and no basket cockles were present at this station. The average biomass for commercial clams was the highest of all stations during both the 1977 and 1978 surveys. The average biomass in 1977 and 1978 was 10.43 and 10.77 kg/m^2, respectively. Butter clams dominated the biomass at this station, accounting for 84 and 87% of the total (Fig. 11). Commercial-size butter clams were also present in the greatest density of any station (i.e., an average of 7.25/0.1 m^2 for 1977 and 1978). In contrast with station A, butter clam recruitment at station C was better in 1977 than 1978. In 1978 only 1% of the butter clams were 20 mm or less, while 26% were of this size in 1977. The above data clearly show this station to possess the best environmental conditions for butter clam populations of any survey station.

Dominance of the clam biomass by butter clams should not lessen the importance of a substantial population of native littleneck clams. In absolute biomass and abundance, the native littleneck population at station C ranks second only to station A (Fig. 11 and Table A-1). The average density of commercial-size native littlenecks at this station during 1977 and 1978 (i.e., 6.6/0.1 m^2) was well above that of any other station on SUBASE Bangor.

The consistent absence of commercial-size Japanese littleneck, basket cockle, and soft-shell clams at this station is notable. From these data it is concluded that station C lacks the necessary set of environmental conditions for successful recruitment and/or survival of these three clam species. In contrast, however, it appears that environmental conditions are extremely favorable for butter and native littleneck clams. The presence of

* Appendix A contains tables and figures for bivalve molluscs of SUBASE Bangor and Indian Island.

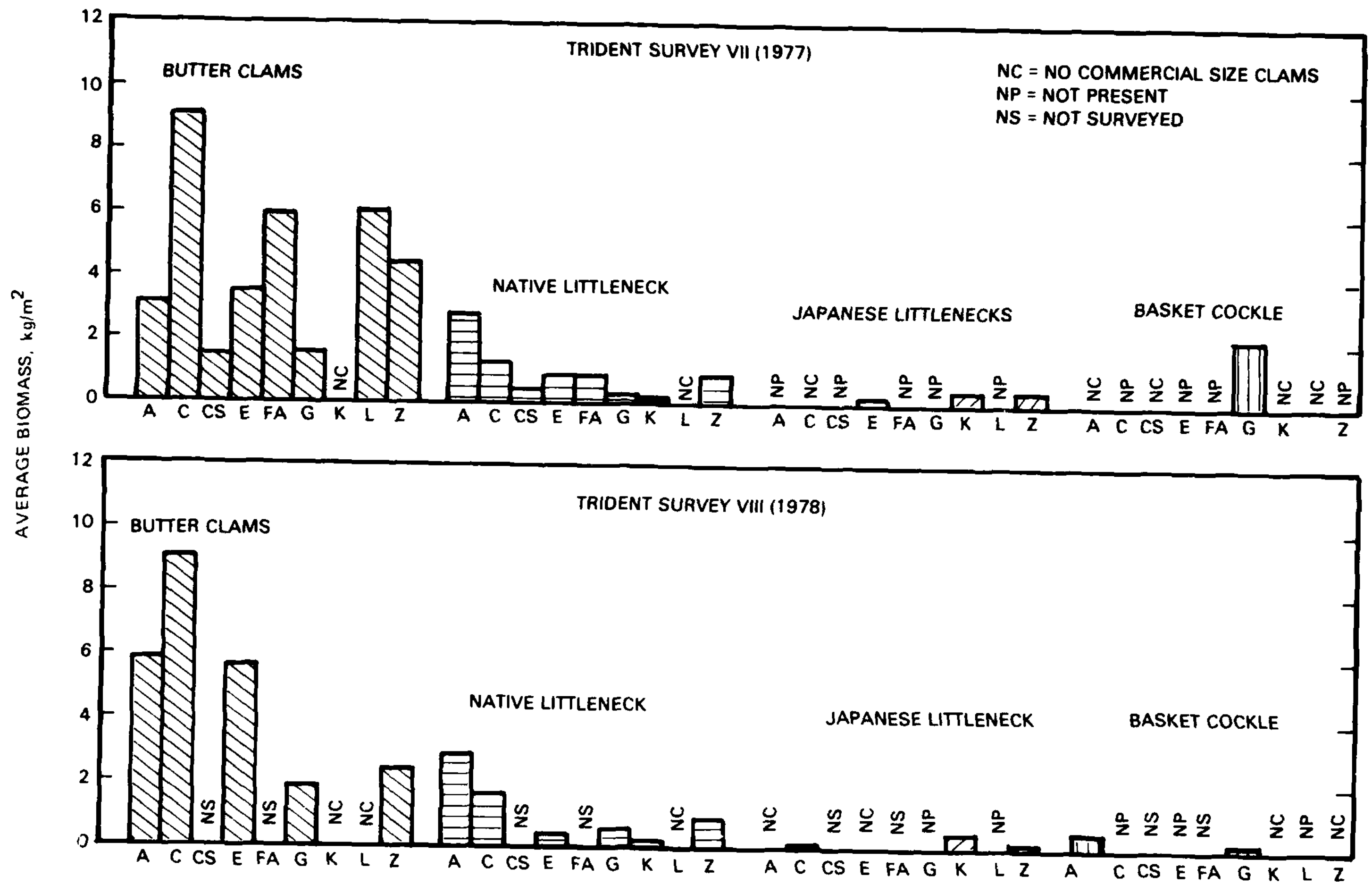

Figure 11. Clam biomass by station and species (commercial sizes only) for 1977 and 1978.

KB Pier and associated Navy activities appears to present no interference to the settlement and growth of the two dominant commercial clam species.

STATION CS (Carlson Spit Boat Ramp)

This station was included in the 1977 environmental survey to determine the potential impact of planned construction upon commercial clam populations. Intertidal digs were made between -2.0 and 0.0 ft in the zone of greatest clam densities. The upper tidal limits for commercial clams at this station determined by random digs were +2.0 ft for native littlenecks and 0.0 ft for butter clams. Japanese littleneck and soft-shell clams were completely absent from this station, while the basket cockle was represented by a single 5-mm specimen. The average biomass of commercial clams was 1.97 kg/m^2, 75% of which was accounted for by butter clams and the remaining 25% by native littleneck clams. Station CS ranks next to last of the Bangor stations in commercial clam biomass; only station K with 0.50 kg/m^2 has less. Incidentally, these two survey stations are the only stations on SUBASE Bangor which do not meet the 2.27 kg/m^2 criterion for classification as a commercially valuable clam bed. The 1977 survey data indicate that recruitment of native littleneck and butter clams did not occur at this station. Only four non-commercial clam species, represented by a total of six individuals, were found at this station.

From these data it can be concluded that the loss of both commercial and non-commercial clams would be minimal as a result of proposed Trident construction at this station. The absence of juveniles and the paucity of adult commercial clams indicate that successful recruitment occurs only occasionally and then only to a minor degree. The species list for this station contains a total of six bivalve species, all of which commonly occur in much greater abundance at other Hood Canal stations.

STATION E

Intertidal digs were made between +4.0 and -1.5 ft, with no commercial clams found above +2.8 ft. No basket cockles were present in the intertidal zone of this station, while Japanese littleneck and soft-shell clams were present in small numbers and very patchy in distribution. In 1977 no soft shell clams were found and in 1978 only one Japanese littleneck. Because of their very patchy distribution, a much more intense survey effort would be required to adequately document the population distributions of these two species at this station.

The average biomass of the remaining two species of commercial clams (i.e., butter and native littleneck clams) was 4.71 kg/m^2 in 1977 and 6.30 kg/m^2 in 1978. These values rank station E second in clam biomass of all the SUBASE Bangor stations. Butter clams accounted for 74 and 90% of the total clam biomass in 1977 and 1978, respectively. Selective harvesting of native littlenecks ("steamers") by recreational clammers may explain the relatively small contribution this species makes to the total clam biomass at this station. Alternatively, it is possible that conditions at this station are more favorable for butter clams than native littlenecks.

The level of recruitment for both native littleneck and butter clams is remarkably low to support such large adult populations. Juvenile clams of these two species represented less than 7% of the total in either of the last two surveys. This, however, is not a recent development, as the 1976 survey found only 4% of the native littleneck clams to be 10 mm or less in length. It is not possible to explain the historical absence of juvenile clams at this station without additional data. It is recommended that future surveys include additional transect lines to the north and south of the present line in order to avoid the influence of the freshwater stream.

STATION FA

This station was surveyed only in 1977 to obtain additional environmental data for a region to be impacted by planned Trident construction. Intertidal digs were made here between +1.5 and −2.0 ft. Station FA had no basket cockles or Japanese littleneck clams and only one soft-shell clam. No commercial clams were found above the +1.5-ft tidal level. Commercial clam biomass was 7.08 kg/m^2 and as with other stations was dominated by butter clams. Butter clams accounted for 84% of the total clam biomass, which is in the 70-90% range found at other SUBASE Bangor stations. Native littleneck clams accounted for 13% and soft-shell clams 3% of the clam biomass. There was no evidence of recent successful recruitment of butter or soft-shell clams and only minor recruitment of native littleneck clams.

Clam biomass values for this station are well above the 2.27 kg/m^2 criterion for commercial importance. All six clam species found at this station are common along the shores of SUBASE Bangor and Puget Sound. Construction activities above the +1.5-ft level would have no impact upon commercial clam populations. However, construction between +1.5 and −1.0 ft would impact significant numbers of adult butter and native littleneck clams. The almost total absence of juveniles (i.e., 0-1 year class) of these species indicates that successful recruitment is not a regular occurrence at the station.

STATION G

Indertidal digs were made between +2.2 and −1.7 ft in the region of major clam populations. The upper tidal limit for native littleneck clams was +2.2 and + 1.7 ft for both butter clams and basket cockles. Japanese littleneck clams were not present in the 1977 or 1978 digs, while only two subcommercial-size specimens were found in 1976.

The average clam biomass was 4.00 kg/m^2 in 1977 and 2.36 kg/m^2 in 1978. In 1977 the total clam biomass was divided among the following: basket cockles 51%, butter clams 40%, and native littleneck clams 9%. Butter clams have never been present in large numbers at this station, averaging only 1 to 2 individuals/0.1 m^2 during most surveys. Basket cockles, however, reach their maximum density, biomass, and recruitment levels here (Tables A-1 and A-2). The average number of small juvenile basket cockles has consistently been between 6.4 and 5.25 individuals/0.1 m^2 since 1976 (Table A-2). However, the survey in June 1978 collected only a few small juvenile basket cockles (e.g., 0.5/0.1 m^2) at this and all other survey stations. In light of this finding, a follow-up survey for basket cockles was conducted at station G by the Trident Environmental Field Office in September 1978. The results of this survey (Table A-2) revealed that basket cockle recruitment had indeed occurred and that the density of juveniles (5.5/0.1 m^2) was within the expected range for this station. Apparently, because the 1978 survey occurred in June instead of July as in 1976 and 1977, juvenile basket cockles had not yet settled out or were still too small to be retained on the sorting screens.

The native littleneck clam population at station G ranks fifth out of the seven SUBASE Bangor stations. Densities for this species have been in the range of 1.0-0.5 individual/0.1 m^2 for the past 3 years. Native littleneck clams accounted for only 9%

of the clam biomass in 1977 and 19% in 1978. These values do not differ greatly from those of the 1976 data, in which native littlenecks accounted for only 8% of the biomass.

Juvenile clam populations and recruitment of commercial species at this station have been quite high relative to the size of the adult population. For example, during the 1976, 1977 and 1978 surveys juvenile clams accounted for 43, 41, and 40% of the butter clams; 78, 75, and 33% of the native littleneck clams; and 88, 81, and 91% of the basket cockles. It appears that hydrographic conditions at this station are favorable for good clam settlement but that the environmental conditions necessary for good clam growth and survival are lacking. Among the natural causes which can explain this observation are: exposure to heavy waves, a high potential for winter kill due to a steep sloping beach (Peeling and Goforth 1975), improper substrate, heavy predation, etc. Since this phenomenon has been observed before, after, and during Trident construction, it is a result of environmental factors unrelated to construction activities.

STATION K

Intertidal digs were made between +3.0 and −1.1 ft. The upper tidal limits for commercial clam species were determined by random digs to be +5.1 ft for native littleneck and butter clams, +3.2 ft for Japanese littlenecks, and 0.0 ft for basket cockles. As in all other surveys, this station again had the smallest clam biomass of any station, with only 0.87 kg/m^2 in 1977 and 0.50 kg/m^2 in 1978. No commercial-size butter clams or basket cockles were found in either survey. Japanese littleneck clams consistently dominated the biomass, accounting for 45 and 84% in 1977 and 1978, respectively.

As observed at station G (the second poorest clam station), juvenile clams were present in high absolute and relative numbers compared to adult clams. The average density of juvenile butter clams (3/0.1 m^2) was exceeded only by station A (4.3/0.1 m^2). The average density of native littleneck clams (3/0.1 m^2) was exceeded only by station C (4.5/0.1 m^2). Paradoxically, stations C and A rank first and second, respectively, in clam biomass, while station K ranks last of all stations. Thus as with station G, conditions are quite favorable for good clam recruitment but extremely poor for growth and survival. The consistency of these observations over the years and the absence of any obvious man-made impacts lead to the conclusion that this phenomenon is a result of natural conditions.

STATION L

Intertidal digs were made between +2.3 and 0.0 ft in the region of major clam populations. The upper tidal limit for native littleneck and butter clams was determined by random digs to be +3.1 ft. A single juvenile basket cockle was present at 0.0 ft and thus cannot be considered representative. Had it not been for the five large butter clams in a single dig in 1977, this station would have ranked last in clam biomass. The following year, no commercial-size clams were found, and in 1976 the total clam biomass (i.e., 0.45 kg/m^2) was accounted for solely by two large butter clams. Thus, in the past three surveys we have found only seven commercial-size butter clams in a total of sixteen intertidal digs. Except for the occasional presence of a few large butter clams the intertidal commercial clam population at this station is extremely depauperate. Additionally, juvenile clam populations and recruitment are also very small, thus further reducing the commercial clam potential of this station. Except for the presence of a fluctuating population of ghost shrimp (*Callianassa* spp. and *Upogebia pugettensis*) and a symbiotic bivalve (*Cryptomya californica*), this station provides only limited data for monitoring environmental conditions and commercial clam populations. It is therefore recommended that this station be eliminated from future surveys and that this effort be redirected into more productive areas.

STATION Z

Intertidal digs were made between +2.9 and –0.3 ft. The upper tidal limits for commercial clam species were determined by random digs to be +5.5 ft for native littlenecks, +5.2 ft for Japanese littlenecks, and +3.4 ft for butter clams. Except for a single juvenile specimen, basket cockles have not been found at this station during the past three surveys.

The average clam biomass was 5.74 kg/m^2 1977 and 3.39 kg/m^2 in 1978, which ranks fifth among the nine survey stations. In 1977, the total clam biomass was divided among the following: butter clams, 77%; native littlenecks, 16%; and Japanese littlenecks, 7%. In 1978, the division of biomass was only slightly different: butter clams, 71%; native littlenecks, 24%; and Japanese littlenecks, 4%.

Recruitment of commercial clams at this station was remarkably high in 1978, with an average density of 24.3 juveniles/0.1 m^2. Survival and growth of juvenile Japanese littleneck clams is also quite high at this station, the biomass of this species ranking second of all survey stations. Recruitment of the more common native littleneck clam was greater here than at all other stations in both 1977 and 1978. The density of adult native littlenecks was also high, ranking fourth and third of all stations in 1977 and 1978, respectively.

Several species of commercial clams exhibit excellent recruitment and survival at this station. Both biomass and densities of these species are sufficiently high to qualify this clam population as commercially important. However, conditions at this station are not suitable for the settlement and growth of either basket cockles or soft-shell clams.

Discussion

Intertidal clam surveys were conducted at nine stations (seven on SUBASE Bangor) in 1977 and at seven station (five on-base) in 1978. Intertidal digs were made principally in the regions of commercial clam populations in order to quantify standing crop (biomass), densities, and recruitment of commercial species. From these data, survey stations can be ranked in their order of importance in terms of these parameters. Clam population statistics from the SUBASE Bangor stations were compared with identical data collected from control stations located off-base. Fluctuations in clam populations that are common to both sites are considered natural and not attributed to Trident construction activities. A data base for commercial clam populations was acquired from eight surveys during the past 5 years (1973-1978) and is an excellent reference for detecting abnormal changes in clam populations. The total biomass of commercial clams at survey stations was generally divided as follows: butter clams, 70-90%; native littlenecks, 10-30%; Japanese littlenecks, 0-7%; basket cockles, 0-5%; and soft-shell clams, 0-5%. An occasional dense patch of one clam species was found at a station, which resulted in an atypical distribution of the biomass. This situation was more common at stations with non-commercial or low clam biomass values (stations G, K and L). In terms of commercial clam biomass per unit area, the stations are ranked in decreasing order as follows: C, A, FA, E, Z, G, L, CS, and K. Stations CS, L and K do not have sufficient clam populations to be classified as commercially or recreationally important. Commercial-size Japanese littleneck clams are found only at stations C, E, K and Z, with the greatest densities occurring at stations K and Z. The recruitment level of juvenile clams was found to be independent of the size of the adult population at a given station. Therefore, it appears that conditions responsible for heavy settlement of juveniles are unrelated to the environmental conditions necessary for good survival and growth. Juvenile clams at stations FA and E represented less than 7% of the total population, yet these stations ranked third and fourth in clam biomass. In contrast, juvenile clams at stations K, CS and L accounted for a much larger percentage (i.e., 23-100% of the butter clams and 33-93% of the native littlenecks); however, these stations ranked ninth, eighth, and sixth, respectively, in clam biomass. This ranking has persisted over 5 years and is thought to be a result of natural conditions (e.g., substrate type, wave action, currents, beach slope).

Conclusions

1. The intertidal commercial clam populations along SUBASE Bangor and the adjacent shoreline are dominated by the following species in decreasing order of abundance; butter clams, native littleneck clams, Japanese littleneck clams, basket cockles, and soft-shell clams.

2. The relative importance of survey stations in terms of commercial clam biomass is as follows: C, A, FA, E, Z, G, L, CS, and K.

3. Levels of recruitment for commercial clams are greatest at stations CS, K and L; however, the number of commercial-size adults (i.e., $\geq$ 30 mm) is quite low, indicating high juvenile mortality. In contrast stations A, C, E, and FA have lower recruitment levels but support significant numbers of commercial-size adults. These data indicate that conditions required for heavy recruitment are unrelated to conditions for good survival and growth.

4. Substantial recruitment of basket cockles (i.e., $\geq 5.0/0.1\ m^2$) has consistently been observed at stations G and A during the past three surveys. The number of small juveniles at either station during the 1978 survey (i.e., only $0.5/0.1\ m^2$) was significantly lower than normal. This may be due to the occurrence of abnormal environmental conditions or the timing of the survey (i.e., June vice July). A special supplemental survey conducted by the Trident Environmental Field Office in September 1978, revealed that basket cockle recruitment did occur and that densities were within normal values (i.e., $5.5/0.1\ m^2$). This finding demonstrated that clam population data can indicate deviations from the norm with the degree of sensitivity that is necessary for a functional biological monitoring program.

5. Commercial clam populations at station L are very small and therefore provide only limited data for monitoring environmental conditions. It is recommended that this station be eliminated from future surveys and that this effort be redirected into more productive areas (e.g., a new off-base control station having larger clam populations).

6. In summary, intertidal clam population data indicate a continuance of environmental conditions that existed prior to Trident construction activities. Clam populations along SUBASE Bangor appear to be experiencing normal recruitment, growth, and survival. Additionally, these clam data show no indication of any detrimental environmental impact resulting from construction activities.

OPTIMAL SAMPLE ALLOCATION FOR SAMPLING INTERTIDAL BIVALVE POPULATIONS AT SUBASE BANGOR

Analysis Rationale

The number and distribution of intertidal samples are important survey design considerations for studies such as those at SUBASE Bangor. Samples are often expensive and time consuming to obtain; however, the reliability of one's results depends heavily upon an adequate data base. There are several statistical approaches that can be taken to deal with this matter. They all require a realistic estimate, based on the literature or a preliminary study of sample variability. Once this requirement is fulfilled, the approach that is chosen will depend upon the experimental design. Thus, one should know exactly what population or physical attributes must be estimated or measured to complete the project.

If one needs to estimate the difference between two means, a simple formula (Sokal and Rohlf, 1969) gives the sample size (n). Required data are: an estimate of sample variance (standard deviation, $s_{\bar{X}}$), the difference that must be detected, the level of significance for the test (α), the probability with which the difference is to be detected, the degrees of freedom associated with the standard deviation, and two values from the t-table. If the objects to be sampled occur in different habitats or locations, then the total area is stratified, and each habitat is called a stratum. The proportion of the sample to be devoted to a stratum (Edmundson and Winberg, 1971) equals

$$\frac{\textit{(population fraction in the stratum) } (s_X \textit{ of the stratum/cost of a sample in that stratum)}}{\text{(sum of the above for all strata)}} .$$

This technique is known as stratified random sampling with optimal allocation. However, if the experimental design is that of an ANOVA (analysis of variance), there are two formulas in Sokal and Rohlf (1969) for determining sample size. By means of a Model II ANOVA (random treatment effects), one formula calculates the standard error of the mean ($s_{\bar{X}}$), given estimated variance components and sample sizes. The objective is to change the sample sizes until the smallest possible $s_{\bar{X}}$ is obtained. The other formula gives sample size as a function of variance components and costs. This formula is called "optimal allocation of effort" and is helpful for those who desire the largest possible sample size within a limited budget.

Analysis Results

The Trident surveys of 1975 through 1978 all sampled station C in July. However, only the data from tidal height zones I, II, and III from 1976, 1977, and 1978 reported sufficient numbers of clams to be included in this analysis. The cost per dig at station C is constant and therefore is not considered in any of the following analyses. The data for *Protothaca staminea* in tidal height zone II were combined for all three years so that a more reliable standard deviation could be calculated. Using the "difference-to-be-dectected" technique, it would take 98 digs at tidal height zone II (station C) to produce a 90% probability of detecting a significant difference of 5 clams between the mean number of clams present in two different years, at $P \leqslant 0.05$. The pilot study had only three digs per tidal height zone per year. The habitat at station C would be unnecessarily disrupted if

98 digs per year were done. There is too much variability in clam densities within replicate digs for this technique to be of much use in allocating the sample effort.

A second technique, stratified sampling with optimal allocation, for allocating sample effort between strata, utilizes the population fraction within the strata, sample variability per stratum (s_x), and the cost of sampling within a stratum. For station C in this case, the several years are combined to provide a better estimate of s_x, and only tidal heights are considered as strata. All three tidal heights were included for this technique, equaling seven digs per year, and the cost per stratum was considered equal to that of each of the others. The results indicate that these seven samples would be better allocated as shown in the table below:

Species	*P. staminea*			*S. giganteus*			*Macoma* sp.		
	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower
Strata (tidal height zones)	I	II	III	I	II	III	I	II	III
Samples/tidal height pilot study	1	3	3	1	3	3	1	3	3
Improved allocation with same total number of samples	0	6	1	0	2	5	0	1	6
Improved allocation; proportion of sample size per stratum	0.00	0.81	0.19	0.00	0.29	0.71	0.00	0.14	0.86

Table 3. Stratified sampling with optimal allocation.

If all three species are considered, optimal allocation of sampling effort involves dropping tidal height I, and doubling the effort at tidal heights II and III from 3 to 6 digs each. Thus total sampling effort per year should be a minimum of 12 digs instead of 7.

Model II ANOVA is used when one is interested in the magnitude of variance components, not in detecting differences between means. A Model II ANOVA was used to calculate variance components from the two factors (i.e., years and tidal heights), interaction between them, and the basic error variance. This variance is that variability between replicated digs. Subgroups were defined by both year and tidal height. The standard error of the mean ($s_{\bar{x}}$) of the subgroups for the available data, was calculated for three species: *Protothaca staminea*, *Saxidomus giganteus*, and *Macoma iris*. Once the variance components and $s_{\bar{x}}$ were known, the sample sizes were changed and $s_{\bar{x}}$ recalculated. The new $s_{\bar{x}}$ is compared to the old $s_{\bar{x}}$ from the pilot study; ideally the new $s_{\bar{x}}$ is smaller. This technique attempts to improve experimental design by lowering the overall variability through improved sampling allocation. The pilot study consisted of three years of two tidal heights with three digs at each tidal height. Tidal height I was dropped because the number of clams per dig was too small. The maximum percent reduction of $s_{\bar{x}}$, relative to the old $s_{\bar{x}}$ from the pilot study, with a minimum addition of new samples, was the same for all three species. The improvement consists of sampling five tidal heights instead of two and doing one dig less per tidal height. Thus, by dropping tidal height I and adding only three more strata (i.e., tidal heights) for a new total of ten digs per year, an improvement of $s_{\bar{x}}$ by 32%

for *Protothaca staminea*, 33% for *Saxidomus giganteus*, and 35% for *Macoma* sp. can be attained at station C. Reviewing the results of all three techniques reveals that a maximum improvment in data precision (i.e., lowering of variability) at station C can be obtained with minimum change. This can be accomplished by dropping one stratum, adding three new strata, and conducting only two digs per strata instead of three.

Conclusions

Three techniques for determining the optimal allocation of sampling effort were examined. Each technique was then applied to the clam density data collected at station C during the Trident surveys in 1976, 1977, and 1978.

1. Variability in clam densities within replicate digs was too large for the first technique ("difference-to-be-detected") to provide a valid recommendation for allocating the sample effort.

2. The stratified sampling with optimal allocation technique recommended dropping tidal height I and conducting 6 digs instead of 3 at both tidal heights II and III. This recommendation requires a new total of 12 digs per year instead of 7.

3. The variance components from the Model II ANOVA technique recommended sampling at five tidal heights instead of three. In addition, only 2 digs instead of 3 per tidal height need to be done, for a new total of 10 digs per year, instead of 7. This design is better than that recommended by the second technique because it achieves an improved sampling design with a minimum number of new digs.

PACIFIC OYSTERS *(CRASSOSTREA GIGAS)* OF SUBASE BANGOR: CONDITION INDICES

Introduction

The general condition or fatness of adult oysters as determined by an oyster condition index has been used to evaluate areas as being "good" or "poor" for oyster growth. Indices used in the past include the condition factor (CF), condition index (CI), and the modified condition index (MCI). For a review and evaluation of these indices see Peeling and Goforth 1975. Attempts at using condition indices to monitor general environmental water quality have been relatively unsuccessful. The major problem in using oyster condition indices has been the inability to adequately distinguish between natural and unnatural fluctuations in oyster condition. Superimposing seasonal and yearly variations in oyster condition upon variations caused by man greatly reduces the sensitivity of condition indices to assess water quality. However, oyster condition measurements were included as a biomonitoring method in Trident surveys VII and VIII to compare oyster growing conditions at the various stations.

Another application of the Pacific oyster in the assessment of water quality is the embryo bioassay developed and refined by the Washington State Department of Fisheries (Woelke, 1967 and 1972). Originally employed to measure the toxic effects of discharge wastes from sulfite pulp mills, the oyster embryo bioassay is now used routinely to monitor water quality of both polluted and unpolluted areas. The increased sensitivity and biological relevance of the oyster embryo bioassay had led to its official acceptance as a measure of water quality by the American Society of Testing Materials.

Materials and Methods

The materials and methods used during surveys VII and VIII were the same as those used during previous Trident surveys. A sample of 10 oysters (*Crassostrea gigas*) was collected from the intertidal zone at approximately the +2.5-ft tidal level from stations C, E, K, Z and Toandos Peninsula. The Toandos Peninsula station, located approximately 400 m south of Brown Point, was chosen as a control site because it appeared least exposed to man-made perturbations. To minimize individual variability, collections were limited to oysters between 90 and 114 mm in length.

Following collection, the oysters were transported to the laboratory and placed in a bucket of seawater. Back at the laboratory an estimate of the relative intensity of spatfall was determined by counting the number of spat on each oyster value. The shells were then brushed to remove barnacles, algae, and debris and placed in a bucket of seawater for 30 minutes. This procedure was followed to eliminate volume errors that could be caused by air trapped inside the valves. Total shell volume of each oyster was then determined by measuring the water displaced from a beaker by immersion of the oyster. The oysters were then opened and the meats removed by severing only the aductor muscle. The meats were then gently blotted and wet weights determined to the nearest 0.1 g. The two shell halves were wiped clean, and their volume determined by water displacement in a graduated cylinder. The volume of the internal shell cavity was calculated by subtracting the volume of the two shell halves from the total shell volume.

The index used to evaluate the oyster condition was the modified condition index (MCI), described by Katkansky et al. (1967),

$$\text{MCI} = \frac{\text{wet meat weight (g)}}{\text{shell cavity volume (ml)}} \times 100.$$

An indication of homogeneity of the means for index values was obtained by calculating the coefficient of variation (CV), which is simply the variance as a percent of the mean (Zar, 1974). The larger the CV, the more heterogeneous (variable) are the data, and the smaller the CV (approaching unity), the more homogeneous the data.

Results and Discussion

In July 1977, the average MCI values for oysters at SUBASE Bangor and Toandos Peninsula were at their highest (i.e., 70.68 and 69.96) since monitoring of oysters began in April 1974 (Fig. 13). At the same time, the Washington Shellfish Laboratory at Quilcene Bay reported that 1977 was an exceptionally good year for spatfall throughout Dabob Bay and Hood Canal. In fact spatfall in July-Aug 1977 was so good that spat settled as far north as South Pt. in Hood Canal. During average years, significant spatfall is confined to Dabob Bay and areas to the south. The spatfall index or set index is determined by the number of spat per oyster shell collected on floating cultch in Dabob Bay. A minimum of 10 spat per adult oyster shell is necessary to make commercial collection of spat economically feasible. Historically the spat index has ranged from 0.1 to 1,000+ (Westley, 1968), with the 1977 index approaching 1,000. Spatfall data for 1977 at the oyster sampling stations are presented in Fig. 12. There is obvious preference for spat to settle onto the shaded bottom valve of an intact adult oyster. This results from the negative phototactic and/or negative geotactic orientation of oyster larvae when they settle out of the plankton (Galtsoff, 1964).

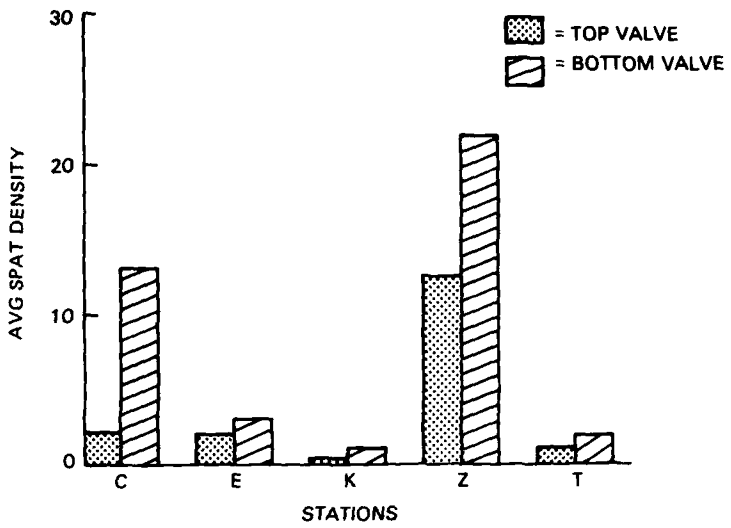

Figure 12. Oyster spat recruitment at SUBASE Bangor and Toandos Peninsula.

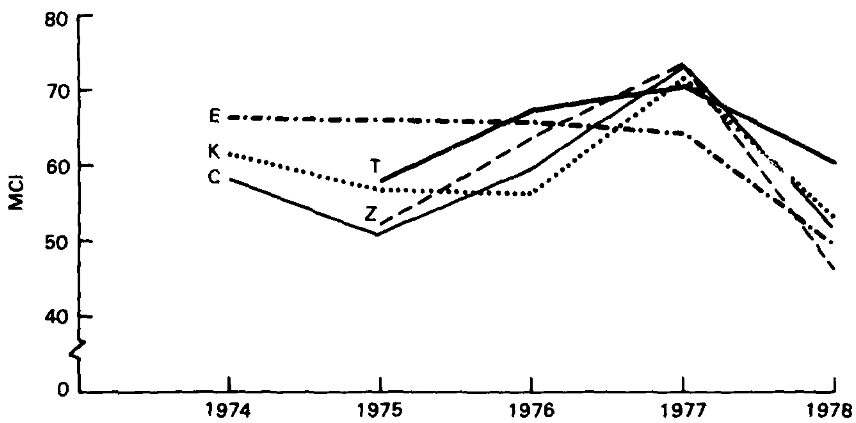

Figure 13. Oyster condition values for SUBASE Bangor and Toandos Peninsula (1974-1978).

Based upon the number of spat on the bottom valve, the spatfall at stations Z and C (i.e., 21.6 and 12.8, respectively) was of commercial intensity. Oysters at stations E, K, and Toandos Peninsula all had less than three spat per bottom valve, a very light spatfall. One must consider, however, that approximately 60% spat mortality can be expected during the first year (MacKenzie, 1970). The spat counted during our survey represent only those surviving for a full 11-12 months. A much higher spatfall index value would have resulted from spat counts obtained in August-September, immediately after settling.

As shown in Fig. 13, oyster condition values (MCI) for June 1978 averaged only 49.07 and contrasted greatly with an average of 70.68 in July 1977. The dramatic drop in oyster condition resulted from a very early spawning season in 1978. Discussions with the Washington Department of Fisheries Shellfish Laboratory revealed that warmer than normal weather conditions caused oysters to begin spawning in June 1978. Normally spawning is delayed until July-August, when water tempertures have been sustained above 18°C for approximately 30 days (Lindsay et al., 1959). This early spawning, which incidentally was as heavy as in 1977 (personal communication Al Schultz, Washington Shellfish Laboratory), will allow for good growth by spat before October, when the cold water conditions return and retard further growth.

Conclusions

1. Oyster condition values were at a maximum in 1977 just prior to a very heavy spawning period.

2. Spatfall along SUBASE Bangor in 1977 reach commercial intensity at both stations Z and C. Spatfall also occurred at stations E and K but was of less than commercial intensity.

3. Oyster conditon values were at a minimum in 1978 just after completion of an abnormally early, intense spawning period.

4. Environmental conditions along SUBASE Bangor appear to be very conducive to good oyster growth, reproduction, and survival. Stations Z and C have excellent conditions for oysters and could support a well-managed harvesting program.

5. It is recommended that future Trident environmental monitoring surveys consider the oyster embryo bioassay because of its greater sensitivity, biological relevance, national recognition, and routine local utilization.

OYSTER BEDS AT CARLSON COVE

Introduction

Pacific oyster (*Crassostrea gigas*) populations along the beaches of SUBASE Bangor have been recreationally harvested for many years. To closely regulate and manage the harvesting of both oysters and clams the Navy has provided a full-time base game warden. In addition to enforcement of size and bag limits, the warden regulates the opening and closing of harvestable areas to insure optimum utilization of oyster stocks. Other efforts to conserve and manage this valuable resource included the physical removal of hundreds of adult oysters from a planned construction site. Prior to construction activities near station E, the Trident Ecology Office organized a transplant of oysters to a more protected area at station K.

To provide the data necessary for continued effective management of Navy oyster resources, NOSC biologists conducted a detailed survey of the previously unharvested oyster beds at Carlson Cove (station C). This survey was designed to determine: (1) the size of the total oyster population, (2) the density of adult oysters, (3) the length and width of the bed, and (4) the intensity of spatfall (i.e., recruitment of juveniles).

Materials and Methods

During low tides on 19 and 20 June 1978 NOSC biologists quantitatively mapped the oyster population of Carlson Cove (i.e., the area between KB Pier and the Carlson Spit boat ramp). Total bed width measurements were made to the nearest 0.1 m at 30-m intervals using a calibrated transect tape. The widths of both the adult and spat zones were also determined to the nearest 0.1 m. Population size and density data were determined along each transect line by counting the oysters in a 1 m^2 quadrat placed at the top, middle, and lower portion of the adult zone. Separate density counts were made for oysters greater and lesser than 2 in long.

Results and Discussion

The Carlson Cove oyster bed begins at a point 46 m south of the KB Pier seawall and extends 560 m to a point 47 m north of the Carlson Spit boat ramp. A detailed map of the bed is presented in Fig. 14, which also contains the zones of spat and adult oysters. The average width of the spat and adult zones is 11.3 and 5.7 m, respectively. The total area covered by the adult oyster zone is 1.28 acres, or 0.519 hectare (i.e., 5,190 m^2), with an average density of 36.8 oysters/m^2. The total number of oysters in the Carlson Cove bed is approximately 191,000. This population is dominated by 176,700 adults greater than 2 in long. The proportionately smaller number of oysters less than 2 in (i.e., only 8% of the total) suggests that this oyster bed has a rather mature, stable population. The presence of large numbers of spat on intertidal rocks, estimated at greater than 1,100/m^2, indicates excellent recruitment and favorable conditions for juvenile development. However, the total absence of adult oysters in the lower spat zone suggests that heavy mortality can be anticipated for the juveniles in this region during the years ahead.

Conclusions

1. The Carlson Cove oyster population contains approximately 191,000 adult oysters, 92% of which are longer than 2 in.

2. Environmental conditions at Carlson Cove have been favorable for the settlement and growth of oyster spat during the past few years. This is evidenced by the presence of approximately 14,300 small oysters less than 2 in long and the high density of spat surviving one year after settlement.

3. The Carlson Cove oyster bed has the characteristics and resources necessary and desirable to allow for a well-managed harvesting program.

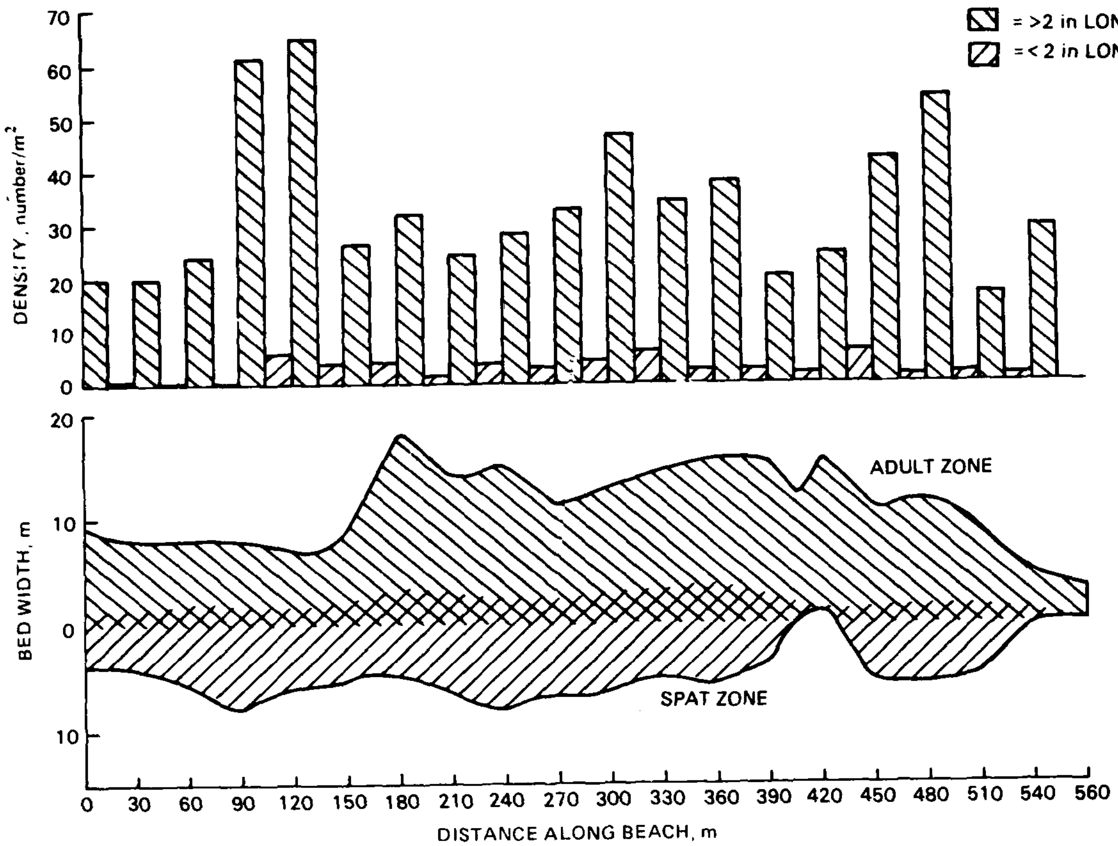

Figure 14. Oyster bed width and density for Carlson Cove (June 1978).

BYSSAL THREAD PRODUCTION BY THE BAY MUSSEL *(MYTILUS EDULIS)* AT SUBASE BANGOR

Introduction

The advantages of using the rate of byssal thread production in mussels to indicate environmental quality have been discussed in previous reports (Salazar, 1974; Peeling and Goforth, 1975). Many investigators have demonstrated a relationship between physical-chemical stress and reduced thread production in the bay mussel, *Mytilus edulis* (Glaus, 1968; Reish and Ayers, 1968; Van Winkle, 1970). This relationship has been used in the laboratory to test the relative toxicity of heavy metals and other pollutants. A portable field bioindicator system has also been developed and tested in San Diego Bay (Salazar, 1974). In these tests, racks containing 50 mussels each were suspended in the water column at a control site to demonstrate that there were no differences in the rate of byssal thread production among racks. If no statistically significant differences occur at the control site, then any differences in thread production between the rack remaining at the control site and racks moved to treatment sites can be attributed to differences in environmental conditions. This technique was used at SUBASE Bangor complex during surveys V, VI, and VII but not during survey VIII.

Materials and Methods

During survey V mussels were collected from the intertidal shoreline on the Toandos Peninsula approximately 400 m south of the Hood Canal Light. During surveys VI and VII mussels were collected from pilings under the light between tidal heights of −1.0 and −3.0 ft (MLLW). Mussels were measured to the nearest millimeter with sliding stainless steel calipers. Only those animals 35 to 45 mm long were used since this is the optimum size for maximum thread production in *Mytilus edulis* (Salazar, 1974). Byssal thread remnants were carefully removed with scissors because pulling them off could have injured the byssal gland and affected thread production. Test animals were acclimatized for 1 week in four plexiglas racks suspended between −1.0 and −3.0 ft in the water column at the Hood Canal Light. This site was selected for collections and as a control because it is across the Canal from SUBASE Bangor and out of the influence of potential pollutants from the facility, is well flushed by currents and appears to be one of the more pristine sites available. Each of 200 test animals was held in a glass crystallizing dish (35 by 50 mm) to facilitate counting and recording. Threads were counted once per day at approximately the same time of day. It took about 30 min per rack of 50 mussels to count and break the threads and record the data. After breaking and counting threads on two consecutive days, three of the racks were moved to the test sites. One rack was left at the Hood Canal Light as a control (station Toandos), while the others were placed at KB Pier, Explosives-Handling Wharf (EHW), and Marginal Wharf (Delta Pier in 1977). Identical procedures were used to obtain thread counts from each station for the next 2 days. In total, the test consisted of 7 days of acclimatization plus 4 consecutive days of data collection. Delta Pier was used instead of Marginal Wharf in 1977 to examine the effects of dredging operations on the rate of thread production at Delta Pier.

Results and Discussion

Duncan's New Multiple Range Test (Duncan, 1955) and Friedman's Non-Parametric Analysis of Variance (Tate and Clelland, 1957) were used to test for statistically significant differences in thread production among days and racks. Data from animals that did not produce any threads during the control period were not used in these analyses. No statistically significant differences were detected among racks during the control period for any survey. This means that any differences in thread production among racks during the treatment period could be attributed to differences in water quality at the different test locations. However, no differences were detected among racks during the treatment period for any survey either. This means that, based on the byssal thread bioindicator, there were no statistically significant differences in water quality among any of the sites during the surveys in 1975, 1976, or 1977. The close similarity in thread production at the sites during those years is shown in Fig. 15.

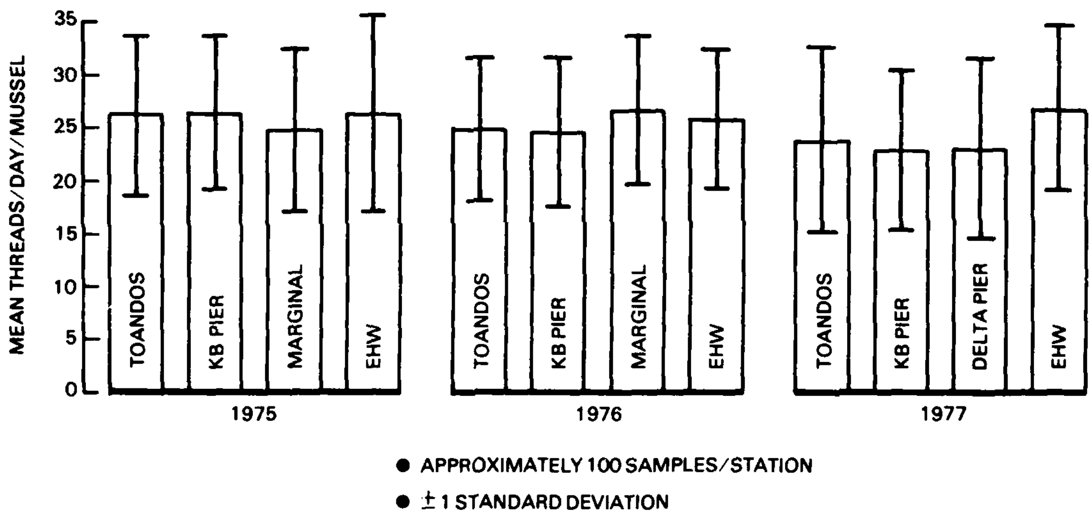

Figure 15. Mean daily thread production by *Mytilus edulis* during treatment periods in 1975, 1976, and 1977.

There were some statistically significant differences in thread production during that same period, however. A few of these differences are obvious when comparing the average thread counts given in Table A-4. Other differences were unclear until the appropriate statistical tests were performed. In 1975 and 1977, there were significant differences in day-to-day thread production (i.e., among days) in particular racks even though there was no difference between racks during the control period or between stations during the treatment period. In other words, the rate of byssal thread production changed each day, but all racks changed similarly. During survey V there was a significant difference between the control and treatment periods that was not detected during surveys VI or VII. Survey VI showed no difference among racks during the control period, among stations during the treatment period, nor among days at each station.

Comparing years, there was no difference between threads produced during the control periods in 1975 and 1977, but the 1976 values were significantly lower. The reason for this lower thread production during the 1976 control period is not really known, but it could possibly be some unmeasured environmental parameter, general animal health, or thread counting error. There was no difference in mean daily thread production during the treatment periods in 1975, 1976, or 1977. When treatment period thread counts for all stations are pooled by years, the average for survey V is 25.61 threads/day/mussel, the average for survey VI is 24.65 threads/day/mussel, and the average for survey VII is 24.0 threads/day/mussel. Mean daily thread production during 1975, 1976, and 1977 was essentially the same during the treatment period.

In comparing thread production rates in Hood Canal with San Diego Bay, other significant differences become apparent. During 9 surveys over a 2-year test period with over 2500 mussels, the avearge for all San Diego Bay stations during the treatment period is 13.61 threads/day/mussel. The mean for Hood Canal stations during 3 surveys and more than 600 mussels during the treatment period is almost twice this value, 24.75 threads/day/mussel. This may be misleading, however, since significant seasonal variation has been observed in byssal thread production in San Diego Bay. There is a definite peak in thread production in San Diego Bay between July and September and a low thread production period between January and March. It is possible that a similar seasonal trend exists for Hood Canal and that the yearly samplings in July bias the data by presenting peak rates of thread production. Even so, the highest mean ever obtained for several stations during a particular survey in San Diego Bay is only 17.01 threads/day/mussel. This is about 50% lower than the mean for the three Trident surveys in Hood Canal. It is possible that the mean of 24.75 threads/day/mussel in the Canal also represents a peak, but there is no evidence to support or refute a significant seasonal fluctuation in thread production.

On the basis of byssal thread production, the results from surveys V, VI, and VII showed no difference in stations at various distances from Trident construction projects. During 1975 there was no construction in progress, and only baseline information was collected. During survey VI the EHW was nearing completion, and significant land clearing had occurred in certain localized areas. At EHW, where pier construction had been underway since 1975, thread production was not significantly different from that of other stations. Land clearing for inland construction increased turbidity within localized areas of the SUBASE Bangor waterfront for a very short time, but the rates of byssal thread production were not affected.

It should be pointed out that most of the waterfront construction during survey VI was minor and that no significant environmental effects were expected. Thus, there should be little difference in the rate of thread production at any station. By survey VII however, most of the waterfront construction was either completed or underway. Any environmental effects attributable to Trident construction should have occurred during the 1977 survey. There were no significant differences in thread production among any of the stations, including the control on the Toandos Peninsula. As mentioned previously, byssal threads were counted at Delta Pier in 1977 instead of Marginal Wharf to investigate the effects of dredging. No significant difference in thread production was detected at Delta Pier, even though dredging occurred during the survey. No significant environmental differences were detected among stations during any of the surveys based on byssal thread production data. This does not mean that there were no environmental differences among stations, but merely that any such differences could not be detected by means of the byssal thread test.

During 2 years of pollution monitoring in San Diego Bay and on the basis of large amounts of data from laboratory toxicity tests, the technique of byssal thread counting has been found to be a valid indicator of environmental stress in mussels. One question to be answered is whether or not this test is sensitive enough to detect subtle differences in water quality among stations. A second question is are the differences between stations indicative of significant differences in environmental water quality?

The byssal thread test as currently conducted with 100 samples, and a standard deviation of about 6.5 can detect differences of about three threads between stations as being significant, according to a statistical formula used to estimate sample size (Sokal and Rohlf, 1969). In past field and laboratory studies, this has been adequate to quantify differences when the difference is large. During surveys V, VI, and VII at SUBASE Bangor no differences were detected. Any differences in water quality that did exist were too subtle to be detected by this bioindicator system, even though there were differences in the rate of byssal thread production. In 1975 and 1977 the standard deviations, means, and coefficients of variation were significantly higher than usual. It is not certain whether these differences were real environmental differences, animal differences, or due to inexperienced thread counters. More laboratory work with a variety of species will be required for comparison with byssal thread data to establish significant detection levels for water quality analyses. It is possible that the sensitivity of detection can be improved by increasing the number of samples, but this sensitivity must be calibrated. The standard deviation can be reduced by using mussels that are more similar in size, age, height in the water column, etc. It has been shown that this is a useful bioindicator system in the laboratory and the field, but further calibration is required to establish a meaningful baseline.

Conclusions

1. There was no significant difference in thread production among stations during any particular year or among years.

2. The summer rate of byssal thread production in Hood Canal is about 50% higher than the summer rate in San Diego Bay, and about 100% higher than the winter rate.

3. Based on the byssal thread bioindicator there was no significant difference in water quality along the SUBASE Bangor waterfront that could be attributed to construction at the Trident facility.

MARINE FISHES OF SUBASE BANGOR

INTRODUCTION

The species composition and relative abundance of fishes that inhabit the marine environs of SUBASE Bangor provide the data that are necessary for any general assessment of the condition of that area. Sampling to collect these data was conducted during Trident survey VII and VIII, July 1977 and June 1978, respectively. The results of the sampling, with emphasis on species composition and density, sexual conditions, and feeding preferences, are the subject of this section. Where applicable, comparisons with previous surveys (Peeling and Goforth, 1975; Peeling et al., 1976) will be presented.

MATERIALS AND METHODS

Stations A, C, K, Z, and FA in July 1977 and stations A, C, E, I, L, and K (Fig. 1) were each sampled by means of a 5-m spread-board otter trawl with a cod-end mesh of 13 mm. The trawl was towed for 10 min which covered approximately 600 m, at a depth of 2 to 7 m. This corresponded to the deep side of the eelgrass beds located at or near each of the stations. One sample collection per station was made in 1977, but in 1978 two collections were made on consecutive days. Species identifications were made in the field when possible, while those species of questionable identification were later identified in the lab by Dr. Richard Rosenblatt, Scripps Institution of Oceanography, La Jolla, California.

The contents of stomachs excised from selected fishes were visually examined for food species composition and abundance. Intestinal contents were not quantitatively examined because advanced digestion makes identification and enumeration of most food items impossible. However, the bivalve content of the intestines of flatfishes may be significant and were therefore examined. Sex and gonadal maturity were determined when possible.

As in previous surveys, inspection was made of all flatfish specimens for the presence of the parasitic nematode *Philometra americana*.

RESULTS AND DISCUSSION

The results of the trawl sampling in 1977 were disappointing in that only 32 specimens representing 8 species were collected (Table B-1*). The sampling was conducted near midday during the early period of an outgoing tide, and no climatological reason for a sparse catch was apparent. Waterfront activity and construction were relatively extensive during the time of the survey and quite possibly affected the number of fishes frequenting the shallow water near construction activities. However, this is a point of conjecture and is not easily quantified.

A total of 428 specimens, representing 20 species of 10 families, were collected during Trident VIII (Table B-2). In general, the more numerous species were represented by small, aggregating fishes: i.e., tubesnout *(Aulorhynchus flavidus)*, pipefish *(Syngnathus leptorhynchus)*, tadpole sculpin *(Psychrolutes paradoxus)*, and shiner perch *(Cymatogaster aggregata)*. The most abundant of the larger fishes was the copper rockfish *(Sebastes caurinus)*.

---

* Appendix B presents tables and figures for the marine fishes of SUBASE Bangor and Indian Island.

The fish catch for Trident VI reported in Peeling et al. (1976) consisted of 240 individuals of 14 species from 8 families. With the exception of survey VIII, when two otter trawl hauls were made per station, only one trawl haul was made at each station during Trident surveys. The number of individuals collected during survey VIII is almost twice that collected during survey VI and reflects closely the doubling of fishing effort.

The fish catch for 1978 yielded five species that were new to the cumulative checklist for the fishes collected during Trident surveys. Two of these species are new records for Hood Canal, based on the list published by De Lacy et al. (1972). The following species are the new listings for Trident catch data, with the first two also representing the new listings for Hood Canal.

Brachyistius frenatus (Kelp perch)
Clinocottus embryum (Calico sculpin)
Hexagrammos stelleri (Whitespotted greenling)
Lumpenus sagitta (Pacific snake prickleback)
Pholis laeta (Crescent gunnel)

The kelp perch is recorded primarily from kelp beds and ranges from Baja California to southern British Columbia (Hart 1973). The kelp perch is a member of the Embiotocidae, surfperch family, and bears live young after a protracted gestation period. The single kelp perch taken at station C was a 113-mm female that contained developing young (length about 19 mm). The presence of developing young within the collected specimen suggests a reproductive population of that species in the vicinity of SUBASE Bangor. However the absence of kelp perch from our trawls during any of the previous seven Trident surveys offers no evidence regarding possible abundance. A comparison with data presented by Hubbs and Hubbs (1954) suggests that the female kelp perch collected at SUBASE Bangor was approximately 2 years old (nearing the maximum age for that species); was going to give birth later in the year than would be expected in California water; and probably inhabited the *Sargassum* bed present at station C. Bane and Bane (1971) reported the following stomach contents from five kelp perch that they examined: "90 percent crustaceans, mostly amphipods and shrimp larvae, and 10 percent algae and benthic diatoms." Bray and Ebeling (1975) reported that kelp perch are often active "cleaners" of other fishes and that as much as 5% of their diet might be derived from that activity. The kelp perch is not of commercial interest.

Hart (1973) reported that the calico sculpin is probably not uncommon in rocky inshore areas and lists the distribution as being from Baja California to the Bering Sea. The calico sculpin is a relatively small fish, reaching a length of 70 mm, and quite probably feeds on small invertebrates that also inhabit shallow water habitats. The calico sculpin is not of commercial interest.

The whitespotted greenling has been recorded from northern California to the Bering Sea (Clemens and Wilby, 1961); however, Fitch and Lavenberg (1971) reported that the specimen from California had been erroneously identified and that the species does not extend that far south. The general habitat for the whitespotted greenling is along rocky shores, but Clemens and Wilby (1961) reported that it is also frequently found in shallow water over sandy beaches. Spawning occurs in April, and the young grow rapidly, reaching a length of 120 mm by August (Hart, 1973). This species reaches a length of 400 mm and is considered a good "eating" fish of some recreational importance.

The remaining two new listings, the snake prickleback and the crescent gunnel, belong to closely related families (Stichaeidae and Pholidae, respectively). Both species are relatively common throughout Washington and British Columbia, but neither is of commercial or recreational importance (Hart, 1973).

In total, 69 copper rockfish *(Sebastes caurinus)* were collected during the 1978 survey. Of these, 30 were young-of-the-year (< 50 mm) and 8 were mature adults (> 250 mm). Young-of-the-year copper rockfish have been collected consistently along the shores of SUBASE Bangor, even in the sparse 1977 catch, and the increased activity of waterfront construction has not had an obvious adverse effect on this species.

The number of English sole *(Parophrys vetulus)* collected in 1978 was greater than during any of the previous seven surveys. The size range of those specimens collected, however, was consistent with previous catches; i.e., all specimens were shorter than 250 mm, and the median size was representative of young-of-the-year or age group I fishes. As reported in Peeling and Goforth (1975), the presence of young-of-the-year English sole in shallow water is not uncommon; however, the increased numbers in 1978, after an extended construction period, is significant.

The catch data for the rock sole *(Lepidopsetta bilineata)* show a trend opposite to that for the English sole, i.e., older fishes, age groups II+, tend to be collected rather than younger fishes. This trend has been consistent over the entire period of Trident surveys and does not appear to be affected by waterfront construction.

The rock sole collected in the vicinity of SUBASE Bangor during the eight Trident surveys have shown a significant infestation by the dracunculoid nemotode *Philometra americana.* Table B-3 presents a summary of these data. The extent of infestation for any one survey in which infested rock sole were collected has ranged from 16 to 46%, with an average infestation of 24.4%. However, if only adult rock sole (> 250 mm) are considered, an infestation of 34.4% is evident. These data are significant in that infestation rates have not increased over the period of Trident construction and do not differ significantly from rates reported for Puget Sound (e.g., 25-43% reported by Wingert et al., 1976). Refer to Peeling and Goforth (1975) and Peeling et al. (1976) for more discussion on this subject.

The stomach contents of 22 fishes representing 5 species were examined for food species composition and abundance. Table B-4 presents the percentage of the examined fishes that contained each food item. Clemens and Wilby (1961) listed the food items for the whitespotted greenling to be worms, crustaceans, and small fishes. The single specimen examined during Trident VIII contained only fish fragments. All but one of the 13 specimens of flatfishes examined contained clam siphon tips and 10 contained polychaete worm fragments. Each of these species of flatfishes is an opportunistic feeder and the food items listed in Table B-4 agree closely with the literature for those species (e.g., Forrester and Thomson, 1969; Kravitz et al., 1976; Hart, 1973). The intestines of the flatfishes were also examined for food item content, and an additional three species of bivalves may be included as food items for the rock sole: *Clinocardium nuttallii, Saxidomus giganteus,* and *Tapes japonica.* The stomachs of eight copper rockfish of age group III+ were examined, and crustaceans were found to be the most utilized food items even though fish fragments were the most abundant single food item. Thirty-eight percent of the copper rockfish examined contained eelgrass *(Zostera marina).* These data for the copper rockfish are consistent with data presented by Prince and Gotshall (1976), in which eelgrass was present in 6.5% of the stomachs, crustaceans and fishes were the most important food groups, and fishes became increasingly more important with age of the rockfish.

CONCLUSIONS

Waterfront construction at SUBASE Bangor was at its peak during 1977, with the bulk of the dredging, delta complex construction, and deperming pier construction being accomplished in that year. A comparison of fish data from Trident surveys VI, VII, and VIII (1976, 1977, and 1978, respectively) indicates a significant decline in species composition and abundance during survey VII but also the complete return to survey VI levels by the time of survey VIII. Although many variables interact to affect fish presence or absence, it is possible that activity along SUBASE Bangor waterfront contributed to the sparse catch of 1977. However, the fish data collected during survey VIII indicate a diverse species composition (428 individuals of 20 species) and a relative abundance that is consistent with that reported in the literature for similar areas. Therefore, even if construction had reduced fish abundance, the decline was temporary and does not appear to be persisting. In fact, the presence of young-of-the-year specimens and sexually mature adults of various species indicates a healthy population of marine fishes that exhibit no detectable evidence of stress from construction activities at SUBASE Bangor.

EELGRASS BEDS OF SUBASE BANGOR

INTRODUCTION

Eelgrass *(Zostera marina)* is one of 50 species of marine flowering plants collectively known as seagrasses. The ecological role of seagrasses has been reviewed by several authors (McRoy and Helfferich, 1977; Thayer et al., 1975; Humm, 1973; den Hartog, 1970; Phillips, 1960 and 1978). The primary productivity of dense seagrass beds has been found to exceed that of cultivated corn, rice, and even phytoplankton populations in regions of upwelling. The energy captured through photosynthesis in seagrass is channeled into the marine ecosystem via several paths: (1) a few organisms (e.g., sea urchins, some ducks and fish) feed directly upon fresh seagrass leaves; (2) detritus-feeding amphipods consume decomposed seagrass leaves and are in turn preyed upon by small fish; and (3) still other organisms (e.g., bacteria and fungi) decompose seagrass detritus into its basic components, which are released into the water column as nutrients to support phytoplankton populations.

Secondary to its role as a primary producer, but equally important, is the protection and shelter eelgrass beds afford shrimp, crabs, and juvenile fish. The leaves also provide a substrate for the attachment of numerous epiphytes and epifaunal invertebrates. Additionally, the epibiota on eelgrass blades provide food for commercial and noncommercial fish species that inhabit the beds on a permanent or seasonal basis.

In addition to its biological role in the marine ecosystem, eelgrass plays an important role in modifying the geological and hydrographical characteristics of an area. Eelgrass leaves act as baffles to reduce water velocity over the bed, thus causing small suspended particles to settle out and become trapped at the base of the plant. In this way eelgrass beds reduce turbidity, stabilize sediments, and attenuate wave action upon the adjacent shore.

In previous Trident environmental surveys eelgrass beds were observed from the mean low water level to a depth of 15 ft along almost the entire shoreline of SUBASE Bangor. Because of the need for eelgrass plants to receive at least 20% relative irradiance to remain healthy, prolonged periods of high turbidity (i.e., more than 2-3 months) can be harmful (Backman and Barilotti, 1976; Burkholder and Doheny, 1968). Water clarity thus determines the depth limits at which eelgrass will grow and affects the biomass and turion densities within a bed. For these reasons eelgrass bed widths, turion densities, and biomass values were determined for stations A, E, K, and L in 1976, 1977 and 1978. Turion density and biomass values were also determined for station FA in 1977.

MATERIALS AND METHODS

Eelgrass bed widths were determined by two scuba divers using a metric transect tape. All bed width measurements were made on a line that was an extension of the intertidal transect line used during bivalve surveys. The same magnetic compass course and point of origin was used to place the transect during each survey.

Biomass and turion density values were determined by the following procedure. Using a pair of scissors, a diver cut all visible turions contained in a 0.1 m^2 sampling ring that was placed in a representative area adjacent to the transect line. Turions were then placed in a meshed collection bag held by a second diver and later transported to the survey boat. This method allowed for turion counts to be made later in the laboratory thus avoiding problems associated with counting in cold, turbid water. Replicate samples were taken at four sites (i.e., 0, 25, 50, and 100%) across wide eelgrass beds (stations E, K and L) and three sites (i.e., 0, 50, and 100%) across narrow beds (stations A and G). In the laboratory leaves were cleaned of debris and turions counted. Turions were then weighed and placed in an oven at 100°C until a constant weight was reached (approximately 24 hours). Dry weights were then determined to the nearest 0.1 g and replicate samples averaged for estimates of standing crop (biomass).

RESULTS AND DISCUSSION

Eelgrass bed widths, biomass, and turion densities were determined for stations A, E, FA, K, and L during survey VII and again during survey VIII (except station FA). During survey VIII, the water content of eelgrass leaves was determined in order to examine the possibility of developing an equation for conversion of wet weights to dry weights. At SUBASE Bangor the water content averaged 89% (in the range 86-92%) for a total of 30 samples. This compares well with the wet-weight-to-dry-weight conversion ratio of 10:1 (i.e., 90%) for eelgrass leaves recommended by McRoy and Helfferich (1977).

Standing crop (biomass) values for eelgrass beds along Hood Canal during a given year showed large variations within individual stations. The central zone of the eelgrass bed (i.e., 25-75% across) was consistently higher in biomass than either the shallow or the deep zones. In contrast, the turion density was often 2 to 3 times greater in the shallow zone than either the central or deep zones. The occurrence of numerous short thin blades in shallow water and long wide blades in deep water has been previously reported by several researchers (Orth, 1977; Harrison and Mann, 1975; Phillips, 1972; Biebel and McRoy, 1971). This morphological variability is thought to be a result of the different environmental conditions (e.g., substrate, temperature and light) of these two zones.

Biomass values for eelgrass beds along SUBASE Bangor and the adjacent shoreline during the past have varied widely (i.e., 20-100%) within a single station. Over the past three years (1976-1978) eelgrass biomass values obtained with replicate sampling have shown no consistent trend. Off-base control stations A and L (Figs. C-1 and C-4*) have shown fluctuations in biomass that were of the same magnitude as the on-base stations E and K (Figs. C-2 and C-3). Both stations K and L experienced a 50% decrease in average biomass from 1977 to 1978. Station E has experienced a 60% decrease in average biomass since 1976, with all but 10% of the reduction occurring between 1976 and 1977. The rather large decreases in eelgrass biomass at stations E and K are very difficult to interpret. However, the unfortunate positioning of the transect line in a region directly influenced by the freshwater streams from Devil's Hole and Cattail Lake may provide at least a partial explanation. The flow pattern of these streams historically has meandered about the intertidal zones of these statons and caused obvious smothering and erosion of established eelgrass plants. Since stations E, K, and the off-base control site station L (which is outside the region of construction influence) all experienced 50% reductions, it may be assumed that these decreases are unrelated to construction activity.

Turion densities determined concurrently with biomass data appear to be of little value as a sensitive water quality monitor. The lack of correlation between biomass and turion densities and the wide range of morphological differences in turions limit the utility of density data. A review of the turion density data for stations E and L (Table C-1) shows that densities have varied from 450 to 220%, respectively, for the shallow zone. Obviously, with such wide variations in turion densities at the control site, these data offer little or no potential as a reliable measure of water quality.

The SUBASE Bangor eelgrass data can be compared with those from other eelgrass beds in Puget Sound. Dr. Ronald Phillips, a local eelgrass specialist (Seattle Pacific College), has extensively studied Puget Sound eelgrass beds (Phillips, 1972). Maximum eelgrass biomass is reported to occur in the summer (June-September) in Puget Sound. The average biomass for two typical Puget Sound eelgrass beds during July was reported to be 108 and 86 g dry weight/m^2. These two values fall within the range of 18-396 g dry weight/m^2 reported as the average biomass for Puget Sound beds during the growing season. The average biomass for the beds at stations A, E, FA, K and L in July 1977 was 91, 67, 76, 106, and 90 g dry weight/m^2, respectively. In July 1978, the average biomass for beds at the same stations (except station FA) was 115, 53, 52, and 49 g dry weight/m^2. These values all fall within the range reported for Puget Sound (i.e., 18-396) and approximate the July values (108 and 86) reported by Phillips for two beds during the period of greatest leaf growth. Phillips (1972) reports the average turion density for Puget Sound eelgrass in the intertidal zone to be 893 turions/m^2 and 151 turions/m^2 in the subtidal zone. The average intertidal turion density for stations A, E, FA, K and L was 1167, 1403, 240, 737, and 1590 turions/m^2, respectively. The rather high values for stations A, E, and L are most likely due to the presence of another eelgrass species, *Zostera noltii*, in the intertidal sample plots. This species of eelgrass has numerous small leaves and occurs primarily in the shallow intertidal regions of the bed. The average subtidal density for stations A, E, FA, K and L was 578, 623, 180, 488 and 355 turions/m^2, respectively. Again these values are closer to that reported by Phillips (i.e., 392) for the subtidal zone of one of the two Puget

---

* Appendix C presents tables and figures for eelgrass beds of SUBASE Bangor and Indian Island.

Sound beds he studied closely. These data comparisons provide the basis for concluding that the eelgrass beds on and adjacent to SUBASE Bangor are approximately average in standing crop (biomass) and above average in turion density. This is most likely due to the dominance of the Hood Canal beds by eelgrass plants which produce leaves that are narrower or shorter than the average for Puget Sound.

CONCLUSIONS

1. Eelgrass standing crop (biomass) and turion density values have shown large fluctuations between 1976 and 1978 at both on-base and off-base stations. For this reason, it is not practical to use these data to monitor environmental water quality.

2. Standing crop values at stations A, E, G, K, and L are average for Puget Sound, while turion densities are slightly above average. This is probably due to the occurrence of eelgrass plants with leaves that are shorter or narrower than the average for Puget Sound.

3. Station FA has only a small eelgrass bed that is average in standing crop and subtidal turion density. The turion density in the intertidal zone at this station is far below average and may reflect less than optimum conditions in this zone.

4. Eelgrass beds at stations E, K, and L show extremely large fluctuations in standing crop and density values. These fluctuations probably result from their constant exposure to natural erosion and siltation forces.

BIOLOGICAL SURVEYS AT INDIAN ISLAND, WASHINGTON (JANUARY AND MAY 1974, JUNE 1978)

INTRODUCTION

The Marine Sciences Division of the Naval Ocean Systems Center was requested by both the Naval Facilities Engineering Command and the OICC Trident to conduct several short-term biological assessment surveys on Indian Island, Washington. The purpose of the first two surveys, in 1974, was to acquire biological baseline data from which possible effects stemming from proposed pier construction could be determined. The purpose of the third survey, conducted in 1978, was to collect biological data to monitor on-going pier construction. These surveys were conducted concurrently with intensive biological surveys being conducted at SUBASE Bangor, Washington.

In January 1974, two biological sampling stations were established at Indian Island (Fig. 16). Station I-C is located on the northwestern side of Walan Point (48° 04′ 22″N, 122° 44′ 46″W) with the transect line running from the high tide line (below the flashing beacon) out to the low tide line on a magnetic heading of 290 deg. The subtidal transect line for Station I-C was displaced northward to a heading of 337 deg to increase the bottom coverage before reaching a depth of 60 ft. Station I-B is located on the south side of Walan Point (48° 04′ 16″N, 122° 44′ 40″W) with the transect line running from the high tide line (below the "U.S. Navy Property" sign) out to the low tide line on a magnetic heading of 165 deg.

Sampling was conducted on 21 January 1974, 6-7 May 1974, and 17-18 June 1978. This section presents the data collected during these periods and a brief discussion of the utility of the data.

BIVALVE MOLLUSCS OF INDIAN ISLAND

The data on the biology, distribution, and density of bivalve molluscs were collected during surveys in January and May 1974 and again in June 1978. The species considered commercially and recreationally important are: the basket cockle *(Clinocardium nuttallii)*, the native littleneck clam *(Protothaca staminea)*, the Japanese or Manila littleneck clam *(Tapes japonica)*, two soft-shell clams *(Mya arenaria* and *M. truncata)*, the Pacific oyster *(Crassostrea gigas)*, two gaper or horseneck clams *(Tresus capax* and *T. nuttallii)*, and the geoduck *(Panope generosa)*.

Intertidal Bivalves

MATERIALS AND METHODS. Intertidal digs were made at stations I-B and I-C along a transect line from the extreme high tide level to the low tide level. Intertidal sampling procedures and techniques were the same as those used at SUBASE Bangor (described earlier in this report).

RESULTS AND DISCUSSION. The relative position and number of digs at each station are depicted in Figs. 17 and 18. Commercial clam biomass data for the 1974 and 1978 biological surveys are presented in Table A-1. Non-commercial species of clams and other intertidal macroforms collected were identified and counted. A cumulative checklist of all organisms identified during surveys at Indian Island is presented in Table D-1*.

* Appendix D presents a cumulative checklist of marine organisms identified during three Indian Island biological surveys.

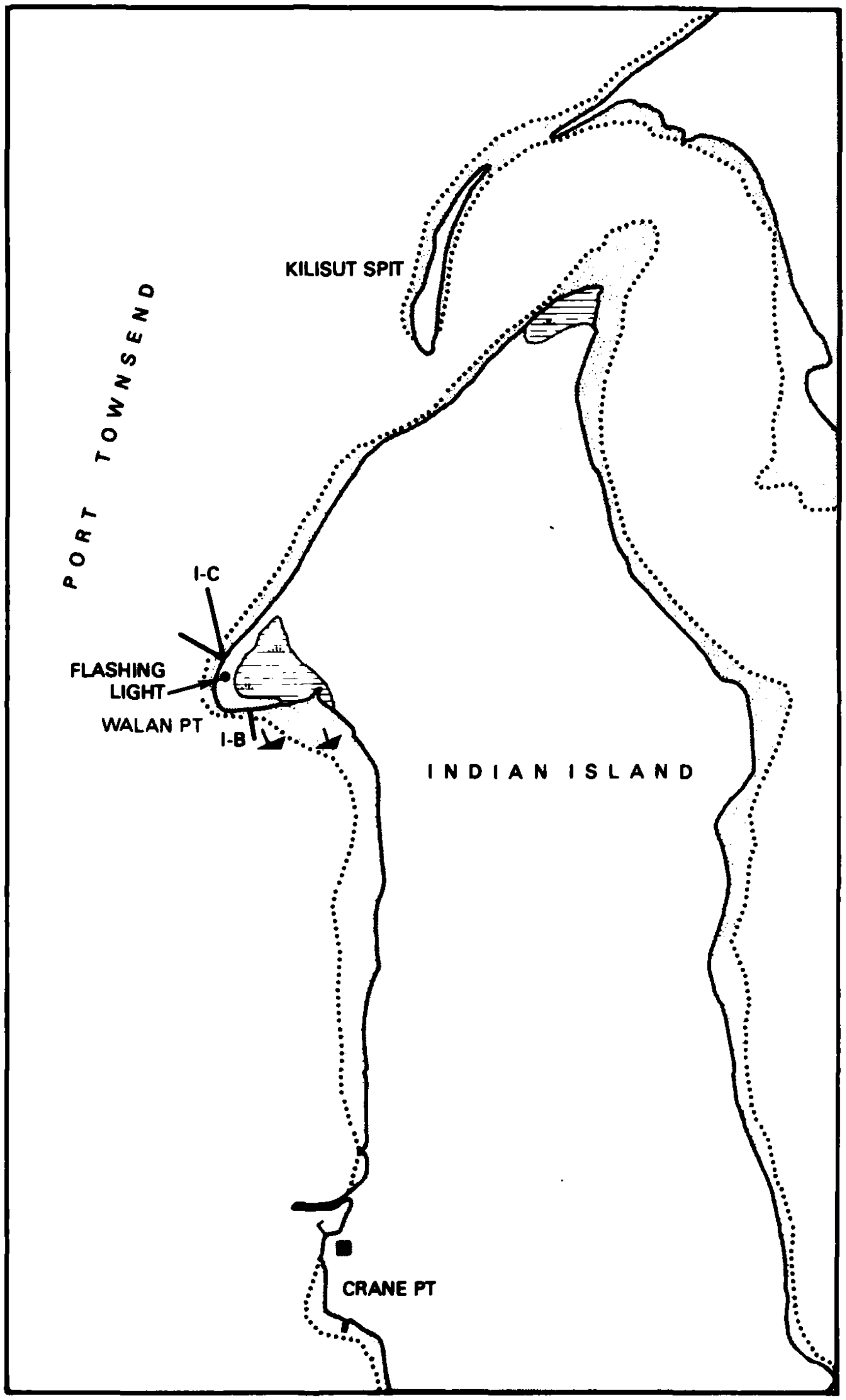

Figure 16. Map of Indian Island showing the location of biological sampling stations.

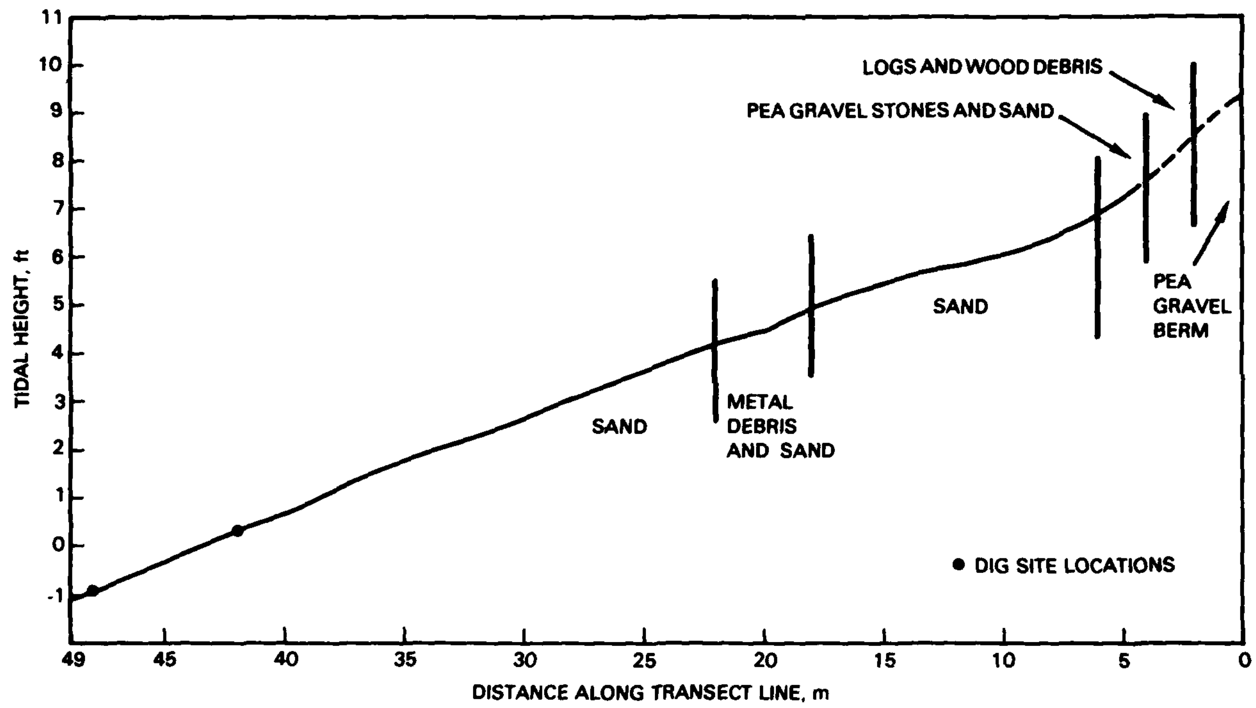

Figure 17. Beach profile at Indian Island station I-B and dig site locations.

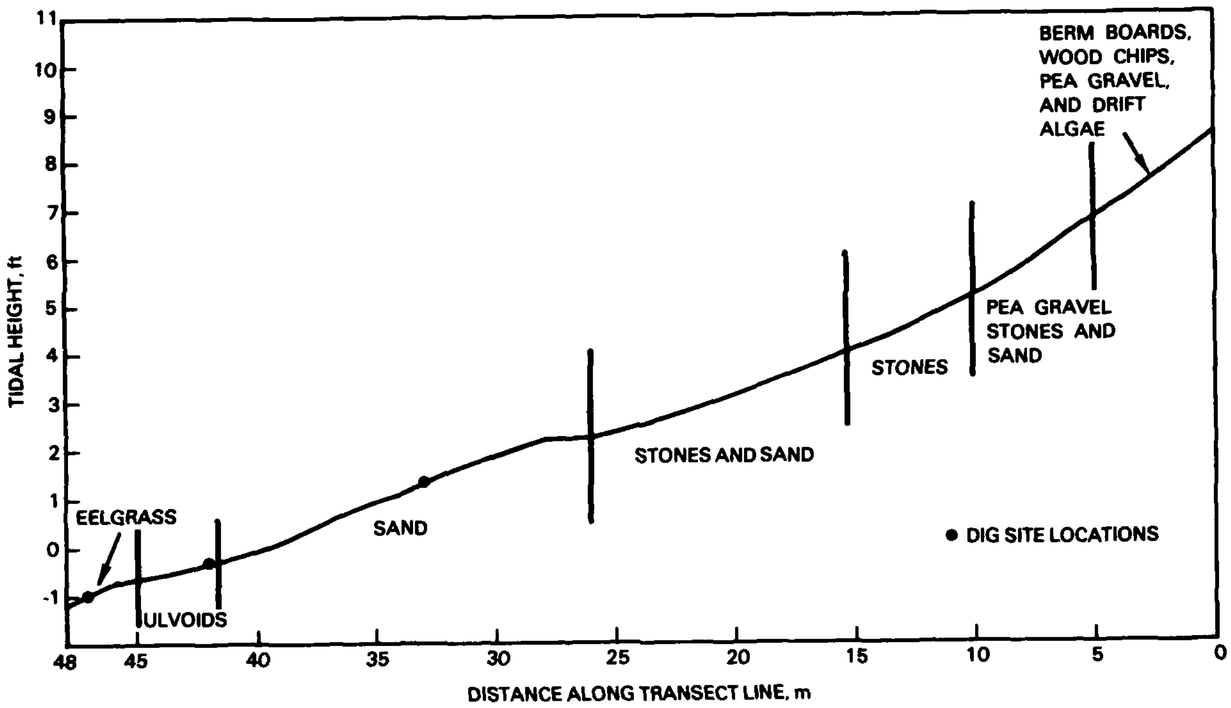

Figure 18. Beach profile at Indian Island station I-C and dig site locations.

Station I-B. No commercial clams were collected at this station during any of the biological surveys. During the three surveys a total of four individual clams representing four non-commerical species *(Macoma inconspicua, M. nausuta, M. secta,* and *Tellina* sp.*)* were collected. Conditions at this station (e.g., substrate, wave action, currents, beach slope) are not favorable for recruitment, growth, and/or survival of commercial or non-commercial bivalves. Scattered clumps of rusting metal located between 18 and 22 m on the transect line (Fig. 17) represent the only intertidal area that supports a biological community of macroforms. Except for this small community of *Balanus* spp., *Mytilus edulis, Acmaea* spp., *Littorina* spp., *Thais emarginata,* and *Hemigrapsus nudus* (barnacles, mussels, limpets, littorines, wrinkled thais, and purple beach crabs) this station provides only limited data for biological monitoring of environmental conditions.

Station I-C. Intertidal digs were made at this station between +1.3 and −1.0 ft. The upper tidal limits for commercial clam species were determined by random digs to be: +1.5 ft for native littleneck clams and +0.9 ft for horseneck and butter clams. During the 3 surveys a total of 34 individuals representing 5 commercial and 3 non-commercial species of bivalves were collected. The only dig in 1974 having commercial-size clams was located at −1.5 ft in the eelgrass *(Zostera marina)* bed and contained a clam biomass of 0.18 kg/ 0.1 m^2. Butter clams accounted for 48% of the biomass, while basket cockles and native littleneck clams each accounted for 26%. In 1978, this dig site was again the only one at this station with a commercial-size clam. However, in 1978 the total clam biomass of 0.10 kg/0.1 m^2 was accounted for totally by a single soft-shell clam. The commercial clam biomass at this station is well below the criteria of commercial importance and is lower than any of the Hood Canal stations. Even though the clam density and biomass at station I-C is much greater than station I-B, the intertidal beach at both stations lacks the environmental conditions necessary for good recruitment, growth, and/or survival of clam populations.

Subtidal Bivalves

INTRODUCTION. The subtidal geoduck and horseneck clam populations at SUBASE Bangor and Indian Island stations were surveyed by NOSC divers. The initial goal was to determine population densities of these subtidal clams prior to and during construction as part of the overall biological data base and monitoring program. Several recent studies (Peeling and Goforth, 1975; Goodwin, 1973 and 1974) have shown that visual counts of subtidal geoducks during the winter months may represent only 10% of the true population. However, during warmer months visual counts may be as high as 60% of the true population. Because of the influence of water temperature upon the number of exposed siphons, the variability of these data is too great to serve as a biological monitor. Subtidal geoduck and horseneck data are included only to provide a conservative estimate of the population densities of these clams at station I-C.

MATERIALS AND METHODS. For subtidal surveys a color-coded transect line was laid perpendicular to the shoreline, extending 350 m out to a water depth of 55-60 ft. Divers descended a buoy line attached to the deep end of the transect line and recorded their observations over increments of 15 m while swimming shoreward. Each diver was equipped with a depth gauge, temperature gauge, color code key, and writing slate with waterproof paper (Ascot, Nalge, Rochester, N.Y.). The use of increments of 15 m allowed the placement and calculation of clam densities at specific distances from shore. Using the survey procedure established by Goodwin of the Washington Department of Fisheries, all geoduck and horseneck siphons visible within 1 m of either side of the transect line were recorded. Geoduck densities were calculated using the total area (transect distance times 2) where they were observed and counted. Horseneck densities were not calculated because of the difficulty in obtaining accurate siphon counts in eelgrass beds, the area of greatest horseneck abundance.

RESULTS AND DISCUSSION. Subtidal geoduck and horseneck clam counts are presented in Table A-5. Based upon these data the subtidal geoduck density at station I-C was estimated at 0.049 clam/0.1 m^2. This estimate compares well with the density of 0.054/0.1 m^2 reported for central Puget Sound and Kilisut Spit (Goodwin, 1973). Goodwin (1973) recommended the following scale for rating geoduck densities: less than 0.06/0.1 m^2 = few, 0.06-0.1/0.1 m^2 = moderate, and greater than 0.1/0.1 m^2 = abundant. Based upon this scale it appears that geoduck populations at station I-C are low and not of commercial densities.

Bivalve Summary and Conclusions

Intertidal bivalve populations at Indian Island stations I-B and I-C on Walan Point can be classified as low or absent. These findings are substantiated by an earlier shellfish survey at Indian Island conducted by the Washington Department of Fisheries (Goodwin and Westley, 1969). From that report the following data were obtained:

a. The Navy owns Indian Island down to the −4.5 ft tidal-height level; 243 acres of bottom is included between +6.0 and −4.5 ft.

b. Of 19 designated survey beaches, numbers 17, 18, and 19 apply to areas at or adjacent to the proposed pier construction area (Fig. 16). Of these three beaches, only number 19 was considered of commercial value (i.e., contained more than 227 g/0.1 m^2 of littleneck and/or butter clams per square foot).

c. Beach 19 was recommended for clam harvest by hand on a once-per-year basis. Beach 17 was considered of marginal importance for consideration as an oyster culture site.

The results of the present survey compare well with the data available for Beaches 17 and 18. Beach 19 was not sampled by NOSC biologists. The data are compared in the following table:

	Beach	No. of Digs	Littleneck Clams Weight (kg/0.1 m^2)	Butter Clams Weight (kg/0.1 m^2)
Dept. of Fisheries	17	47	0	0
NOSC	17	3	0	0
Dept. of Fisheries	18	12	0.027	0.054
NOSC	18	3	0.014	0.027
Dept. of Fisheries	19	6	0.18	0.268

Table 4. Comparison of shellfish survey results at Indian Island conducted by the Washington Department of Fisheries and NOSC.

Based upon the data from these clam surveys and the available literature, the following conclusions are presented:

1. Both intertidal and subtidal populations of commercial clams at stations I-B and I-C fall below the recognized densities and standing crop values to be considered commercially or recreationally important.

2. Station I-B has an extremely depauperate intertidal clam population and a total absence of commercial clam species.

3. Pier construction activities at station I-B would have no impact upon commercial clam populations and only minor impact at station I-C.

EELGRASS BEDS OF INDIAN ISLAND

Introduction

The rationale for surveying eelgrass *(Zostera marina)* beds as part of this biological survey and a review of the pertinent literature have been presented earlier in this report (see page 43) and will not be repeated here.

Materials and Methods

The materials and methods used to survey the eelgrass bed at Indian Island (i.e, station I-C) were identical to those used at SUBASE Bangor stations (p. 43).

Results and Discussion

The bed width, turion density, and biomass for the eelgrass bed at station I-C are presented in Fig. C-5 and Table C-1. The eelgrass bed near this station begins just north of Walan Point and extends at least 100 m north of the station I-C transect line. The bed varies from 20-120 m in width, and in 1978 was 24 m wide at station I-C. The intertidal turion density of this bed ($785/m^2$) was slightly below the average for Puget Sound ($860\text{-}968/m^2$) reported by Phillips (1972). The subtidal density ($255/m^2$) however, was slightly above the average for Puget Sound ($75\text{-}247/m^2$). The standing crop of eelgrass at station I-C was 146 g/m^2, which is higher than any Hood Canal station (range 52-134 g/m^2) or beds at nearby Whidby Island (range 86-108 g/m^2) as reported by Phillips. The value of 146 is, however, well within the range of 18-396 g/m^2 reported for Puget Sound during the summer season (Phillips, 1972).

Conclusions

1. A substantial eelgrass bed is present at station I-C, extending from Walan Point to at least 100 m north of the transect line.

2. The eelgrass in this bed appears to be of average density and above average biomass.

3. This eelgrass bed will probably be temporarily reduced in size and biomass during pier construction activities as a result of reduced light penetration and physical disruption.

4. Any permanent loss of eelgrass as a result of pier construction will probably be confined to the area immediately adjacent to the pier.

MARINE FISHES OF INDIAN ISLAND

Fish sampling at Indian Island consisted of conducting a single 10-min otter trawl tow at each of stations C and B. Additionally a similar tow was conducted across the area between those two stations (Fig. 16). The tows were made through eelgrass beds for the most part, with the exception of the area around Walan Point.

A total of 62 individuals representing 13 species from 8 families were collected on 17 June 1978 (Table B-5). The most numerous species was the tadpole sculpin (*Psychrolutes paradoxus*), which had a size range of 25-33 mm (mean 28.6 mm). Hart (1973) reported that in southern British Columbia young tadpole sculpin between 12 and 22 mm are present in the plankton during the month of April. The size range for tadpole sculpin collected at Indian Island in June suggests that these specimens were young-of-the-year that had just recently settled to a benthic habitat from the plankton.

The following species of flatfishes were collected: *Lepidopsetta bilineata* (rock sole), *Parophrys vetulus* (English sole) and *Platichthys stellatus* (starry flounder). As was observed at SUBASE Bangor, the specimens of English sole collected were young-of-the-year and age group I (63-176 mm). Stomach-content analysis of the rock sole revealed a diet of crustaceans (amphipods, crabs, and shrimp) and clams (siphons and *Transenella tantilla*). The starry flounder was found to have been feeding on shrimp and the clam *T. tantilla*.

None of the fish species collected at Indian Island are uncommon for Admiralty Inlet (the body of water adjacent to Indian Island) as noted by De Lacy et al. (1972). Therefore, based upon this survey data it appears that the marine fishes in the area of construction are typical representatives of similar habitats in this region.

REFERENCES

Backman, T. W. and D. C. Barilotti. 1976. Irradiance reduction: effects on standing crops of eelgrass (*Zostera marina* L.) in a coastal lagoon. Mar. Biol. 34: 33-40.

Bane, G. W. and A. W. Bane. 1971. Bay Fishes of Northern California. Mariscos Publications, New York, 143 pp.

Biebel, R. and C. P. McRoy. 1971. Plasmatic resistance and rate respiration and photosynthesis of *Zostera marina* at different salinities and temperatures. Mar. Biol. 8(1): 48-56.

Bourne, N. and D. W. Smith. 1972. Breeding and growth of the horse clam, *Tresus capax* (Gould), in southern British Columbia. Proc. Nat. Shellfish. Assoc. 62: 38-46.

Bray, R. N. and A. W. Ebeling. 1975. Food activity and habitat of three "picker-type" microcarnivorous fishes in the kelp forest off Santa Barbara, California. Fish. Bull. 73(4): 815-829.

Burkholder, P. R. and T. E. Doheny. 1968. The biology of eelgrass. Contrib. 3, Dept. of Conservation and Waterways, Town of Hempstead, Long Island, New York, 120 pp.

Butler, P. A. 1965. Reaction of estuarine mollusks to some environmental factors. Pages 92-104, *in* C. M. Tarzwell, ed., Biological Problems in Water Pollution, Third Seminar, Aug. 13-17, 1962. U.S. Dept. Health, Education, and Welfare, Cincinnati, Ohio, Publ. 999-WP-25.

Clemens, W. A. and G. V. Wilby. 1961. Fishes of the Pacific coast of Canada. 2nd ed. Fish. Res. Bd. Can., Bull., (68): 1-443.

DeLacy, A. C., B. S. Miller, and S. F. Borton. 1972. Checklist of Puget Sound Fishes. Univ. Wash. Dept. Mar. Res. Sea Grant Publ. WSG72-3, 43 pp.

den Hartog, C. 1970. Seagrasses of the world. North-Holland Publishing Co., Amsterdam. 280 pp.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11: 1-42.

Edmundson, W. T. and G. C. Winbert. 1971. A manual on methods for the assessment of secondary productivity in fresh waters. Pages 185-197 *in* International biological program handbook, 17. Oxford Blackwell Scientific Publications. 358 pp.

Fitch, J. E. and R. J. Lavenberg. 1971. Marine food and game fishes of California. Univ. Calif. Press, Berkeley. 155 pp.

Forrester, C. R. and J. A. Thomson. 1969. Population studies on the rock sole *(Lepidopsetta bilineata)* of northern Hecate Strait, British Columbia. Fish. Res. Bd. Canada Tech. Rpt. 108, 104 pp.

Galtsoff, P. S. 1964. The American Oyster, *Crassostrea virginica* (Gmelin). U.S. Fish. Bull. No. 64, 480 pp.

Glaus, K. J. 1968. Factors influencing the production of byssus threads in *Mytilus edulis*. Bio. Bull. Mar. Biol. Lab., Woods Hole 135: 420.

Goodwin, C. L. 1973. Distribution and abundance of subtidal hard-shell clams in Puget Sound, Washington. State of Washington Dept. of Fisheries Tech. Rept. No. 14, 81 pp.

Goodwin, C. L. 1974. The effects of season on visual and photographic assessment of subtidal geoduck clam (*Panose generosa* Gould) populations. Veliger 20(2): 155-158.

Goodwin, C. L. and R. E. Westley. 1969. Shellfish potential of navy-owned tidelands on Indian Island and eastern side of Toandos Peninsula. Washington Dept. Fish. Final Report (mimeo).

Harrison, P. G. and K. H. Mann. 1975. Detritus formation from eelgrass (*Zostera marina* L.): the relative effects of fragmentation, leaching, and decay. Limno. and Oceanogr. 20: 924-934.

Hart, J. L. 1973. Pacific Fishes of Canada. Fish. Res. Bd. Canada Bull. 180, 740 pp.

Holland, D. A. and K. K. Chew. 1974. Reproductive cycle of the Manila clam (*Venerupis japonica*), from Hood Canal, Washington. Proc. Nat. Shellfish. Assoc. 64: 53-58.

Hubbs C. L. and L. C. Hubbs. 1954. Data on the life history, variation, ecology and relationships of the kelp perch, *Brachyistius frenatus*, an Embioticida fish of the Californias. California Fish and Game 40(2); 183-198.

Humm, H. J. 1973. Seagrasses. Pages III C-1 to III C-10 *in* J. I. Jones et al., eds. A summary of knowledge of the eastern Gulf of Mexico. Amer. Petrol. Inst. Washington, D.C.

Katkansky, S. C., A. K. Sparks, and K. K. Chew. 1967. Distribution and effects of the endoparasitic copepod, *Mytilicola orientalis*, on the Pacific oyster, *Crassostrea gigas*, on the Pacific coast. Proc. Nat. Shellfish. Assoc. 57: 50-58.

Kravitz, M. J., W. G. Pearcy and M. P. Guin. 1976. Food of five species of cooccurring flatfishes on Oregon's continental shelf. Fish. Bull. 74(4): 984-990.

Lindsey, C., R. E. Westley, and C. S. Sayce. 1959. Prediction of oyster setting in the state of Washington. Proc. Nat. Shellfish. Assoc. 49: 59-70.

MacKenzie, C. L., Jr. 1970. Causes of oyster spat mortality, conditions of oyster setting beds, and recommendations for oyster bed management. Proc. Nat. Shell. Assoc. 60: 59-67.

Mann, R. and S. J. Glomb. 1978. The effect of temperature on growth and ammonia excretion of the Manila clam *Tapes japonica*. Estuarine and Coast. Mar. Sci. 6: 335-339.

McRoy, C. P. and C. Helfferich. 1977. Seagrass ecosystems. Marcel Dekker, Inc., New York. 314 pp.

Nickerson, R. B. 1977. A study of the littleneck clam (*Protothaca staminea* Conrad) and the butter clam (*Saxidomus giganteus* Deshayes) in a habitat permitting coexistence, Prince William Sound, Alaska. Proc. Nat. Shell. Assoc. 67: 85-102.

Nosho, T. Y. and K. K. Chew. 1971. The setting and growth of the Manila clam, *Venerupis japonica* (Deshayes), in Hood Canal, Washington. Proc. Nat. Shell. Assoc. 62: 50-58.

Ohba, S. 1959. Ecological studies in the natural population of a clam, *Tapes japonica,* with special reference to seasonal variation in the size and structure of population and to individual growth. Biol. J. Okayama Univ. 5: 13-42.

Orth, R. J. 1977. Effect of nutrient enrichment on growth of the eelgrass *Zostera marina* in the Chesapeake Bay, Virginia, USA. Mar. Biol. 44: 187-194.

Paul, A. J. and H. M. Feder. 1973. Growth, recruitment, and distribution of the littleneck clam, *Protothaca staminea,* in Gallena Bay, Prince William Sound Alaska. Fishery Bull. 71: 665-677.

Pearce, J. B. 1965. On the distribution of *Tresus nuttallii* and *Tresus capax* (Pelecypoda: Mactridae) in the waters of Puget Sound and the San Juan Archipelago. The Veliger 7: 166-170.

Peeling, T. J. and H. W. Goforth. 1975. Trident biological surveys: a summary report, June 1973–July 1975. Naval Undersea Center, San Diego, CA, Technical Publication No 510. 144 pp.

Peeling, T. J., M. H. Salazar, J. G. Grovhoug, and H. W. Goforth. 1976. Trident biological survey: July 1976. Naval Undersea Center, San Diego, CA, Technical Publication No. 510, Supplement 1. 55 pp.

Phillips, R. C. 1960. Observations on the ecology and distribution of the Florida seagrasses. Fla. State Bd. Conserv. Mar. Lab., Prof. Papers Series. No. 2. 72 pp.

Phillips, R. C. 1972. The ecological life history of *Zostera marina* L. (eelgrass) in Puget Sound, Washington. Ph.D. dissertation, University of Washington. Seattle, Wash. 153 pp.

Phillips, R. C. 1978. Seagrass and the coastal marine environment. Oceanus 21(3): 30-40.

Prince, E. D. and D. W. Gotshall. 1976. Food of the copper rockfish, *Sebastes caurinus* Richardson, associated with an artificial reef in south Humbolt Bay, California. Calif. Fish and Game 62(4): 274-285.

Ratti, F. D. 1977. Reproduction and growth of the Pacific basket cockle *Clinocardium nuttallii* Conrad, from intertidal and subtidal environents of Netarts Bay. Masters Thesis. Oregon State Univ. Corvallis, Ore. 99 pp.

Reish, D. J. and J. L. Ayers. 1968. Studies on the *Mytilus edulis* community in Alamitos Bay, California. III. The effects of reduced dissolved oxygen and chlorinity concentrations and byssus thread formation. Veliger 10: 384-388.

Salazar, M. H. 1974. Byssal thread production as a toxicity test, *in* Proceeding of the Conference on Marine Biology in Environmental Protection. Naval Undersea Center TP 443.

Simon, J. L. and J. P. Dauer, III. 1972. An evaluation of siltation by bay dredging and construction company during oyster-shell dredging operations in Tampa Bay, FL. Research Report *for* Bay Dredging and Construction Co., Tampa, FL. 60 pp.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco, CA. 776 pp.

Swan, E. F. 1952. The growth of the clam *Mya arenaria* as affected by the substratum. Ecology 33: 530-534.

Tate, M. W. and R. C. Clelland. 1957. Nonparametric and shortcut statistics. Interstate Printers and Publishers, Inc., Danville, Ill. 110 pp.

Thayer, G. W., D. A. Wolfe, and R. B. Williams. 1975. The impact of man on seagrass systems. American Scientists 63: 288-296.

Van Winkle, W. 1970. Effect of environmental factors on byssal thread formation. Mar. Biol. 7: 143-148.

Westley, R. E. 1964. Some relationships between Pacific oyster *(Crassostrea gigas)* condition and the environment. Proc. Nat. Shellfish. Assoc. 55: 19-33.

Westley, R. E. 1968. Relation on hydrography and *Crassostrea gigas* setting in Dabob Bay, Washington. Proc. Nat. Shellfish Assoc. 58: 42-45.

Wingert, R. C., B. B. McCain, K. V. Pierce, S. F. Borton, D. T. Griggs, and B. S. Miller. 1976. Ecological and disease studies of demersal fishes in the vicinity of sewage outfalls. *In* 1975 Research in Fisheries, Annual Report of the College of Fisheries, Univ. of Washington, Contribution No. 444.

Woelke, C. E. 1967. Measurement of water quality with the Pacific oyster embryo bioassay. Water Quality Criteria, ASTM STP 416, Am. Soc, Testing Mats. pp 112-120.

Woelke, C. E. 1972. Development of a receiving water quality bioassay criterion based on the 48-hour Pacific oyster *(Crassostrea gigas)* embryo. Washington Dept. of Fisheries. Technical Report No. 9. 93 pp.

Zar, J. H. 1974. Biostatistical analysis. Englewood Cliffs, Prentice-Hall, Inc.

APPENDIX A

Tables and Figures for Bivalve Molluscs of SUBASE Bangor and Indian Island

Species

Bangor Stations		Butter Clam	Native Littleneck	Japanese Littleneck	Basket Cockle	Soft Shell Clams	Total Biomass
A	77	3.12	2.76	NP	NC	NP	5.88
	78	5.91	2.95	NC	0.48	0.54	9.88
C	77	9.09	1.34	NC	NP	NP	10.43
	78	9.03	1.64	0.10	NP	NP	10.77
CS	77	1.50	0.47	NP	NC	NP	1.97
E	77	3.50	0.95	0.14	NP	0.12	4.71
	78	5.69	0.32	NC	NP	0.29	6.30
FA	77	5.97	0.95	NP	NP	0.16	7.08
G	77	1.61	0.35	NP	2.04	NP	4.00
	78	1.91	0.45	NP	0.11	NC	2.36
K	77	NC	0.08	0.39	NC	0.40	0.87
	78	NC	0.08	0.42	NC	NP	0.50
L	77	*6.13	NC	NP	NC	NP	6.13
	78	NC	NC	NP	NP	NP	NC
Z	77	4.41	0.92	0.41	NP	NP	5.74
	78	2.40	0.85	0.14	NC	NP	3.39
Indian Island Stations							
B	74	NP	NP	NP	NP	NP	0.0
	78	NP	NP	NP	NP	NP	0.0
C	74	0.08	0.05	NP	0.05	NP	0.18
	78	NP	NC	NP	NP	0.10	0.10

NC = No commercial size clams
NP = Not present
* One dig with (5) five large specimens

Table A-1. Biomass of commercial clam beds (avg. kg/m^2) by station and species (1977 and 1978).

	Species				
	Butter Clam	Native Littleneck	Japanese Littleneck	Basket Cockle	Soft Shell Clams
STA-A					
1977	4 (3.6)	8 (2.8)	NP	0 (6)	NP
1978	7 (5.0)	9.5 (3.0)	NP	0.5 (0.5)	1 (0)
STA-C					
1977	5.7 (2.0)	5.9 (5.0)	NP	NP	NP
1978	8.8 (0.8)	6.6 (4.0)	1 (0)	NP	NP
STA-CS					
1977	2.0 (1.3)	1.7 (0.7)	NP	0 (1)	NP
STA-E					
1977	4.3 (0.3)	4.0 (0.3)	1.5 (0.5)	NP	NP
1978	6.5 (0)	1.0 (0.3)	0 (0.3)	NP	0.3 (1.0)
STA-FA					
1977	6.0 (0.2)	3.0 (0.8)	NP	NP	NP
STA-G					
1977	1 (0.7)	0.5 (1.5)	NP	1.5 (6.4)	NP
1978	1.2 (0.8)	1.0 (0.5)	NP	0.5 (0.5)	1 (0)
STA-K					
1977	0 (5)	0.3 (4.0)	1.7 (4.3)	0 (3.5)	1.5 (0)
1978	0 (1)	0.5 (2.0)	3.7 (5.0)	NP	NP
STA-L					
1977	5 (0)	0 (1)	NP	NC	NP
1978	0 (1)	0 (1)	NP	NP	NP
STA-Z					
1977	4.1 (1.4)	3.3 (9.0)	2 (4)	NP	NP
1978	2.3 (1.7)	4 (5)	1.3 (24.3)	0 (1)	NP

Densities of Basket Cockles at Station G

	1976 (July)	1977 (July)	1978 (June)	1978 (Sept)
STA-G	1 (5.25)	1.5 (6.4)	0.5 (0.5)	0.5 (5.5)

Notes: Density values = average number of commercial sized (i.e., ⩾ 30mm) or sub-commercial sized individuals per $0.1 m^2$ for digs having commercial species present.

Density values in parentheses are for sub-commercial sized clams.

NP = Not present.

Table A-2. Density of commercial clam species at Bangor survey stations (1977 and 1978).

Station	25 April 1974 MCI	25 April 1974 CV (%)	25 July 1975 MCI	25 July 1975 CV (%)	9 July 1976 MCI	9 July 1976 CV (%)	6 July 1977 MCI	6 July 1977 CV (%)	23 June 1978 MCI	23 June 1978 CV (%)
C	58.63	34	50.90	15	59.60	20	73.09	8	58.86	8
E	66.60	19	65.80	22	65.95	11	64.33	16	49.54	22
K	61.46	19	56.50	17	56.46	15	71.75	19	52.00	13
Z	–	–	52.80	18	68.85	11	73.53	12	42.87	18
χ	62.23	24	56.60	18	61.46	14.25	70.68	13.75	49.07	15.25
Toandos Peninsula	–	–	57.90	25	66.73	14	69.96	12	60.52	16

MCI: modified condition index
CV: coefficient of variation

23 June 1978
Number of Spat Per Valve

Station	Top	Bottom
C	2.3	12.8
E	2.2	2 9
K	0.2	1.3
Z	12.4	21.6
Toandos Peninsula	1.1	2.2

Table A-3. Comparative oyster condition data for SUBASE Bangor and Toandos Peninsula (1974-1978).

1975			1976			1977		
Station	Mean	Standard Deviation	Station	Mean	Standard Deviation	Station	Mean	Standard Deviation
Toandos			Toandos			Toandos		
Day 1 & 2	28.25	8.02	Day 1 & 2	24.12	6.87	Day 1 & 2	26.43	9.33
Day 3 & 4	25.93	7.53	Day 3 & 4	24.79	6.81	Day 3 & 4	23.70	8.75
KB Pier			KB Pier			KB Pier		
Day 1 & 2	28.17	8.11	Day 1 & 2	23.68	6.34	Day 1 & 2	26.92	8.86
Day 3 & 4	26.21	7.33	Day 3 & 4	24.43	6.98	Day 3 & 4	22.80	7.55
Marginal			Marginal			Delta Pier		
Day 1 & 2	27.13	7.09	Day 1 & 2	25.34	5.36	Day 1 & 2	26.85	10.21
Day 3 & 4	24.74	7.60	Day 3 & 4	26.42	6.96	Day 3 & 4	23.07	8.50
EHW			EHW			EHW		
Day 1 & 2	26.45	9.29	Day 1 & 2	23.07	7.55	Day 1 & 2	27.87	9.21
Day 3 & 4	26.29	9.10	Day 3 & 4	25.72	6.49	Day 3 & 4	26.64	7.71

- All Stations 1975

Day 1 & 2 $\overline{x} = 27.19$ $\overline{SD} = 8.13$ $n \approx 400$

Day 3 & 4 $\overline{x} = 25.61$ $\overline{SD} = 7.89$ $n \approx 400$

$\overline{\overline{x}} = 26.4$ $\overline{\overline{SD}} = 8.01$ CV = 30.81

- All Stations 1976

Day 1 & 2 $\overline{x} = 23.77$ $\overline{SD} = 6.53$ $n \approx 400$

Day 3 & 4 $\overline{x} = 24.65$ $\overline{SD} = 6.81$ $n \approx 400$

$\overline{\overline{x}} = 24.21$ $\overline{\overline{SD}} = 6.67$ CV = 24.21

- All Stations 1977

Day 1 & 2 $\overline{x} = 27.02$ $\overline{SD} = 9.40$ $n \approx 400$

Day 3 & 4 $\overline{x} = 24.00$ $\overline{SD} = 8.13$ $n \approx 400$

$\overline{\overline{x}} = 25.51$ $\overline{\overline{SD}} = 8.77$ CV = 34.38

Table A-4. Mean daily thread production by *Mytilus edulis* (approximately 100 samples/station).

Transect Line Distance (m)*	Depth (ft)	Side**	Geoducks	Horsenecks
350 - 335	55 - 53	L	3	0
		R	3	0
335 - 320	50	L	0	0
		R	2	0
320 - 305	–	L	5	0
		R	3	0
305 - 290	47	L	3	0
		R	0	0
290 - 275	45	L	5	0
		R	0	0
275 - 260	–	L	2	0
		R	6	0
260 - 245	–	L	6	0
		R	7	0
245 - 230	33	L	4	0
		R	7	0
230 - 215	–	L	31	1
		R	26	0
215 - 200	21	L	13	0
		R	28	0
200 - 185	–	L	2	0
		R	6	0
185 - 170	11	L	0	7
		R	0	3
	Total		162	11

* Distance from estimated high tide mark.
** Side = Left (L) or right (R) side of transect line where counts for two 1-m-wide paths were obtained.

Table A-5. Indian Island subtidal geoduck and horseneck counts at station I-C (6 May 1974).

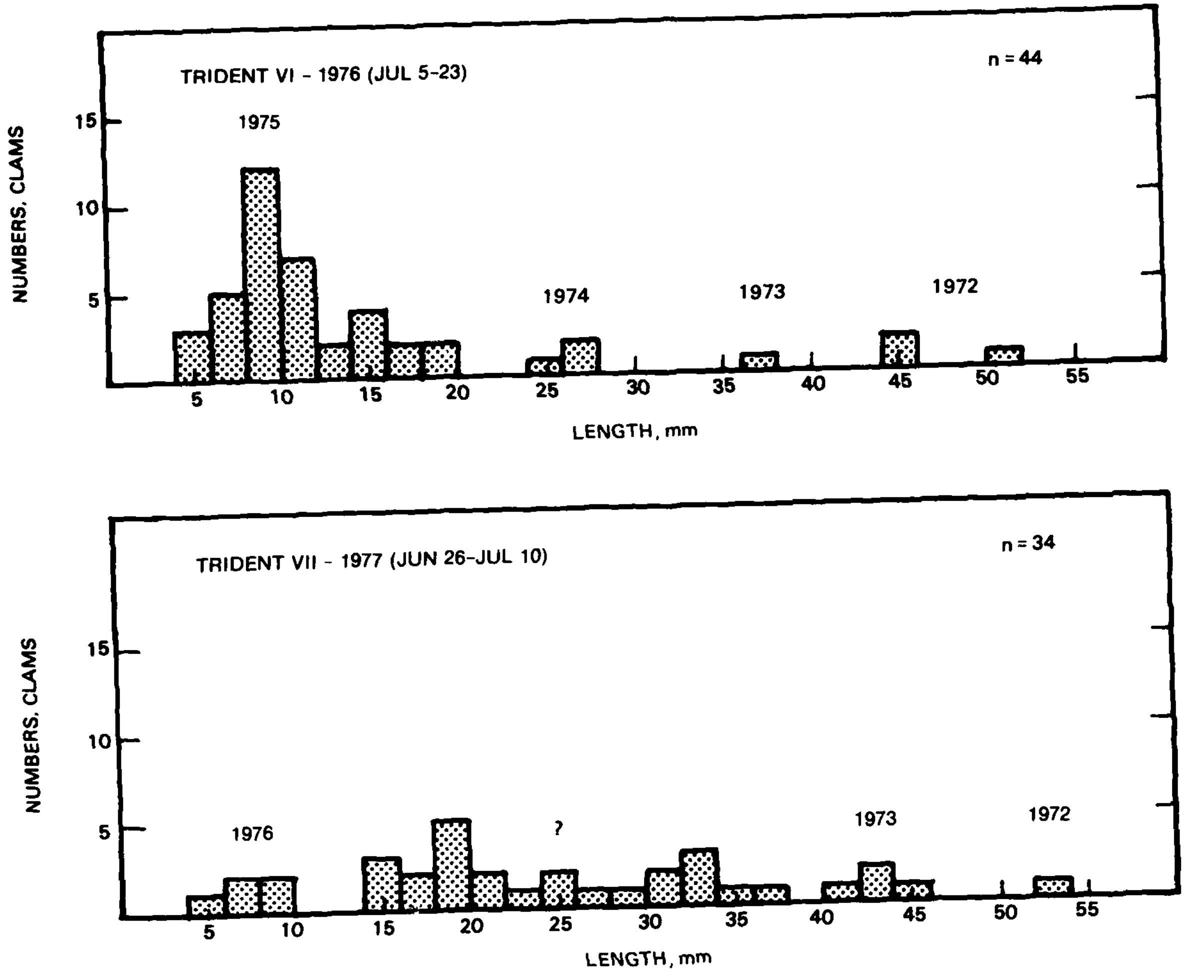

Figure A-1. Length-frequency distribution of Japanese littleneck clams, *Tapes japonica* in June-July 1976 and 1977.

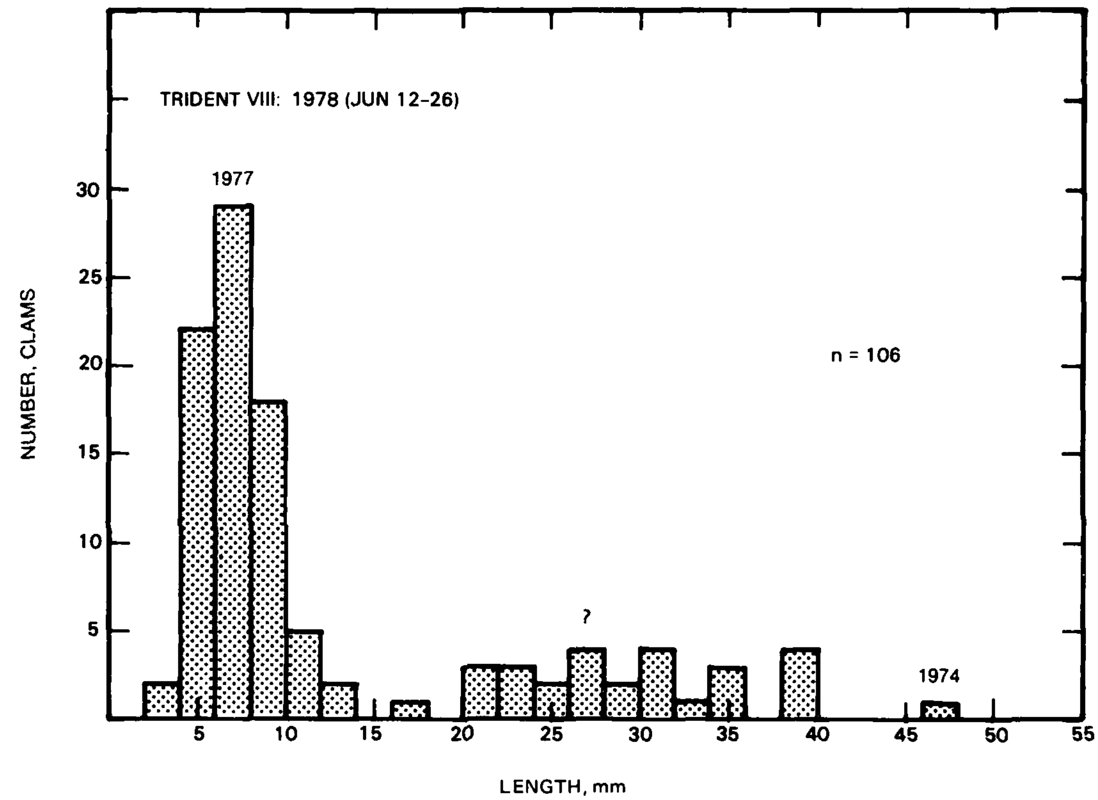

Figure A-2. Length-frequency distribution of Japanese littleneck clams *(Tapes japonica)* in June 1978.

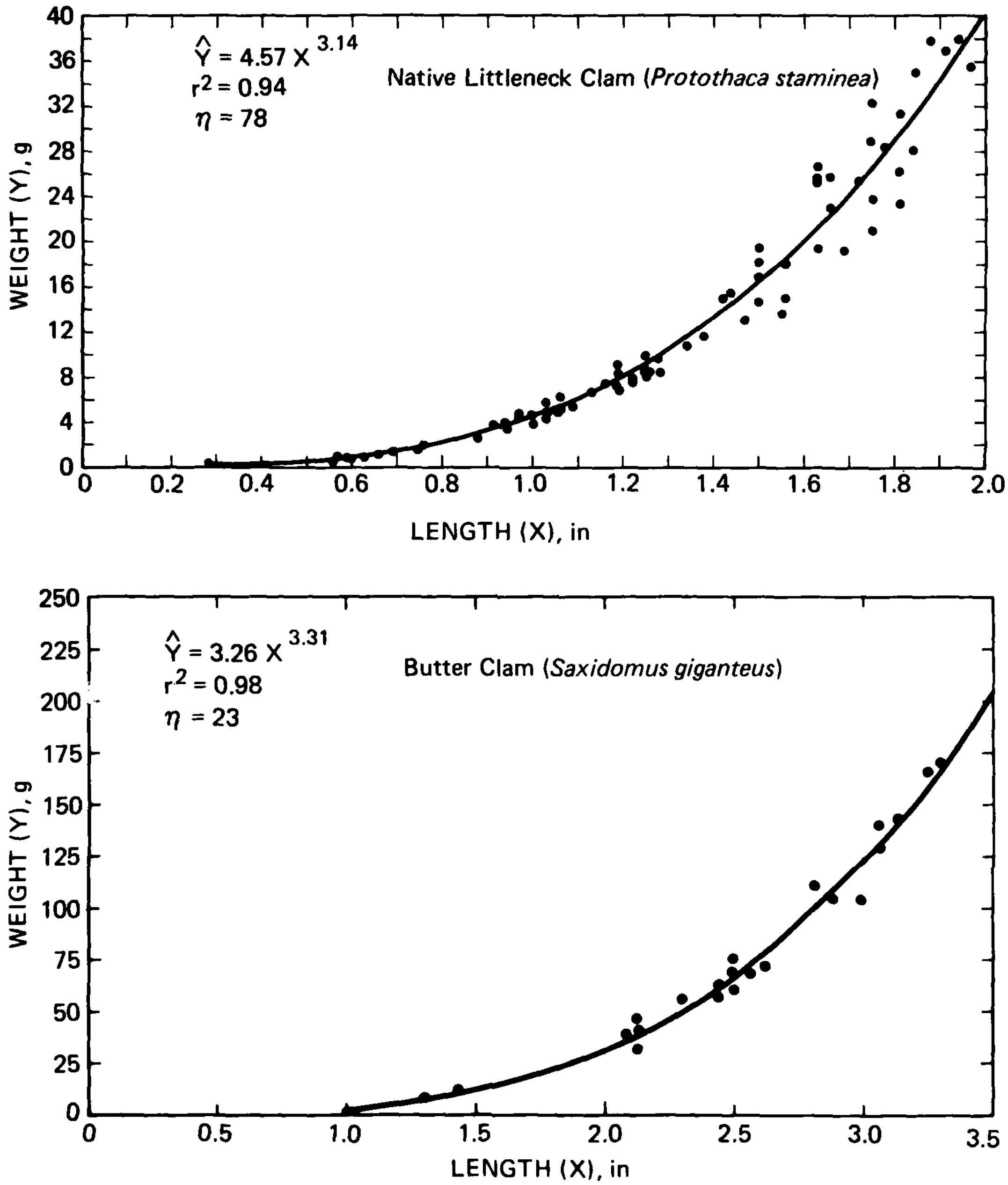

Figure A-3. Length: Weight relationships for the native littleneck clam *(Protothaca staminea)* and the butter clam *(Saxidomus giganteus)*.

APPENDIX B

Tables and Figures for the Marine Fishes of SUBASE Bangor and Indian Island

	A	C	K	Z	FA	Total
Gasterosteidae						
Tube-Snout			6			6
(*Aulorhynchus flavidus*)						
Embiotocidae						
Shiner Perch	1	5	1	9		16
(*Cymatogaster aggregata*)						
Striped Perch					1	1
(*Embiotoca lateralis*)						
Pholidae						
Gunnel		1				1
(*Apodichthys flavidus*)						
Scorpaenidae						
Copper Rockfish	4					4
(*Sebastes caurinus*)						
Cottidae						
Pacific Staghorn Sculpin	1					1
(*Leptocottus armatus*)						
Tadpole Sculpin					1	1
(*Psychrolutes paradoxus*)						
Pleuronectidae						
Rock Sole	1				1	2
(*Lepidopsetta bilineata*)						
Total number of individuals	7	6	7	9	3	32
Number of species	4	2	2	1	3	8

Table B-1. Fish species composition and abundance during Trident survey VII (July 1977).

Family and Species	Sta. A 1	2	Sta. C 1	2	Sta. E 1	2	Sta. I 1	2	Sta. L 1	2	Sta. K 1	2	Total 1978	1977	1976
Gadidae															
Pacific Tomcod															
(*Microgadus proximus*)									1				1		4
Gasterosteidae															
Tube-Snout															
(*Aulorhynchus flavidus*)				1		1			36	4	28		70	6	99
Syngnathidae															
Pipefish															
(*Syngnathus leptorhynchus*)					4	1		1	14	26	4	5	55		
Scorpaenidae															
Copper Rockfish															
(*Sebastes caurinus*)	13	13	5	24	5	3	3	1			2		69	4	23 (+25)
Hexagrammidae															
Whitespotted Greenling															
(*Hexagrammos stelleri*)			1								1		2		
Cottidae															
Padded Sculpin															
(*Artedius fenestralis*)							2		4				6		
Calico Sculpin															
(*Clinocottus embryum*)										1			1		
Pacific Staghorn Sculpin															
(*Leptocottus armatus*)					3	1				6		9	19	1	1
Tadpole Sculpin															
(*Psychrolutes paradoxus*)							1		32		43	1	77	1	
Embiotocidae															
Kelp Perch															
(*Brachyistius frenatus*)			1										1		
Shiner Perch															
(*Cymatogaster aggregata*)			3			1	2	2	3	11		31	53	16	20
Striped Perch															
(*Embiotoca lateralis*)			1	1		1							3	1	16
Pile Perch															
(*Rhachochilus vacca*)				1			2	1				8	12		
Stichalidae															
Pacific Snake Prickleback															
(*Lumpenus sagitta*)									1				1		
Pholidae															
Penpoint Gunnel															
(*Apodichthys flavidus*)									1				1	1	
Crescent Gunnel															
(*Pholis laeta*)			1						1	2			4		
Saddleback Gunnel															
(*Pholis ornata*)										1			1		4
Pleuronectidae															
Rock Sole															
(*Lepidopsetta bilineata*)		1	1	5				2	3		4		16	2	22
English Sole															
(*Parophrys vetulus*)		1	1	1	1				4	25	2		35		6
CO Sole															
(*Pleuronichthys coenosus*)											1		1		12
Total number of individuals	13	15	14	33	13	8	10	7	100	76	85	54	428	32	240
$\overline{x}$ number of individuals	14		23.5		10.5		8.5		88		69.5		214	32	240
Total number of species	3		10		7		7		14		11		20	8	10

1 = Otter trawl sampling conducted 15 June 1978
2 = Otter trawl sampling conducted 16 June 1978

Table B-2. Fish species composition and abundance during Trident surveys VI, VII and VIII (June-July 1976-1978).

	Adult			Juvenile		
Survey	> 250 mm	(Infested)	%	< 250 mm	(Infested)	%
II (Oct 1973)	9	(5)	56	3	(0)	0
III (Jan 1974)	32	(7)	22	13	(0)	0
IV (May 1974)	23	(5)	22	7	(0)	0
V (July 1975)	1	(0)	0	3	(0)	0
VI (July 1976)	17	(10)	59	5	(0)	0
VII (July 1977)	1	(0)	0	1	(0)	0
VIII (June 1978)	10	(5)	50	6	(0)	0
Total	93	(32)	34.4	38	(0)	0

Table B-3. Occurrence of *Philometra americana* infestation in juvenile and adult rock sole collected during Trident surveys II-VIII.

Species	Sex (Male: female: unknown)	Fish Fragments	Polychaete Fragments	Butter Clam (*Saxidomus giganteus*)	Tellen Clam (*Tellina* sp.)	Siphon tips	Crustacean Fragments	Amphipods (*Caprellids and Gammarids*)	Crab (*Cancer* sp.)	Black-clawed crab (*Lophopanopeus bellus*)	Shrimp	Brittle Star (*Ophiuroids*)	Plants (*Zostera; Ulva*)	Empty Stomachs
Whitespotted Greenling (***Hexagrammos stelleri***)	0:1:0	100												
Rock Sole (***Lepidopsetta bilineata***)	5:3:3		73	9		91	36	18			9	18	45	9
English Sole (***Parophrys vetulus***)	0:1:0		100		100	100		100						
CO Sole (***Pleuronichthys coenosus***)	0:1:0		100			100							100	
Copper Rockfish (***Sebastes caurinus***)	5:3:0	50					29	14	38	14	38		38	14

Note: Stomach contents are presented as the percentage of the designated fish species which contained the food item.

Table B-4. Results of stomach-content analyses of selected fishes collected during Trident survey VIII.

	Collection Sites			
Family and Species	C	CB	B	Total
Gadidae				
Pacific Tomcod (*Microgadus proximus*)		1		1
Gasterosteidae				
Tube-Snout (*Aulorhynchus flavidus*)	3	6	1	10
Hexagrammidae				
Whitespotted Greenling (*Hexagrammos stelleri*)			1	1
Cottidae				
Silverspotted Sculpin (*Blepsias cirrhosus*)	2	1		3
Tadpole Sculpin (*Psychrolutes paradoxus*)	7	20	2	29
Stichaeidae				
Pacific Snake Prickleback (*Lumpenus sagitta*)	2			2
Pholidae				
Penpoint Gunnel (*Apodichthys flavidus*)	1	2		3
Crescent Gunnel (*Pholis laeta*)	1			1
Cyclopteridae				
Pacific Spiny Lumpsucker (*Eumicrotremus orbis*)	1			1
Slipskin Snailfish (*Liparis fucensis*)		1		1
Pleuronectidae				
Rock Sole (*Lepidopsetta bilineata*)	2			2
English Sole (*Parophrys vetulus*)	7			7
Starry Flounder (*Platichthys stellatus*)	1			1
Total Number of Individuals	27	31	4	62
Total Number of Species	10	6	3	13

Table B-5. Fish species composition and abundance during Indian Island survey (June 1978).

APPENDIX C

Tables and Figures for Eelgrass Beds of SUBASE Bangor and Indian Island

Station	Distance Across Bed, m (percent)	Density Turions/m^2 n = 2			Biomass g dry wt/m^2 n = 2			Percent Water n = 2
		1976	1977	1978	1976	1977	1978	1978
A	1 (0)	1380	1170	950	115	51	98	88
	10 (50)	1820	400	355	112	136	146	90
	20 (100)	340	310	245	117	85	102	91.5
E	1 (0)	2220	1540	450	232	152	38	89
	23-25 (25)		190			53		
	30-33 (33)	2180		605	122		60	88
	60-66 (66)	1680		360	111		62	90
	68-74 (75)		110			37		
	90-99 (100)	170	110	205	69	27	51	90
FA	(0)		240			79		
	(100)		180			73		
G	(0)	1510			48			
	(50)	830	–	–	65	–	–	–
	(100)	200			64			
K	1 (0)	1050	800	360	64	98	32	88
	23 (25)		570			105		
	30 (33)	890		655	91		82	88
	60 (66)	720		550	110		64	88.5
	68 (75)		390			121		
	90 (100)	110	340	170	26	98	31	91
L	1 (0)		2190	990		84	46	87
	22 (33)			870			82	86
	34 (50)		220			79		
	45 (66)			230			47	90
	68 (100)		270	185		106	22	90
Indian Island C	1 (0)			785			107	88
	12 (50)			295			166	87
	24 (100)			215			165	86

Table C-1. Hood Canal and Indian Island eelgrass beds, density and biomass data (1976-1978).

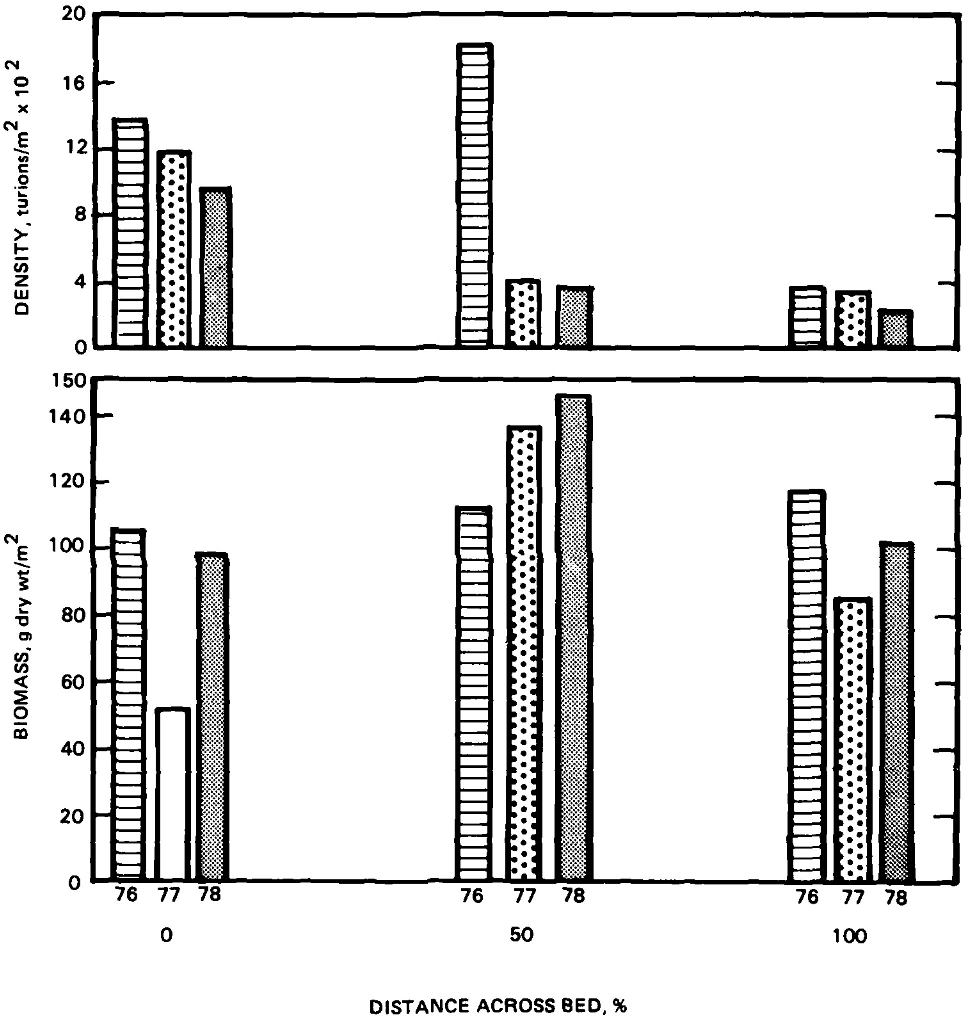

Figure C-1. Station A eelgrass bed density and biomass profiles (1976-1978).

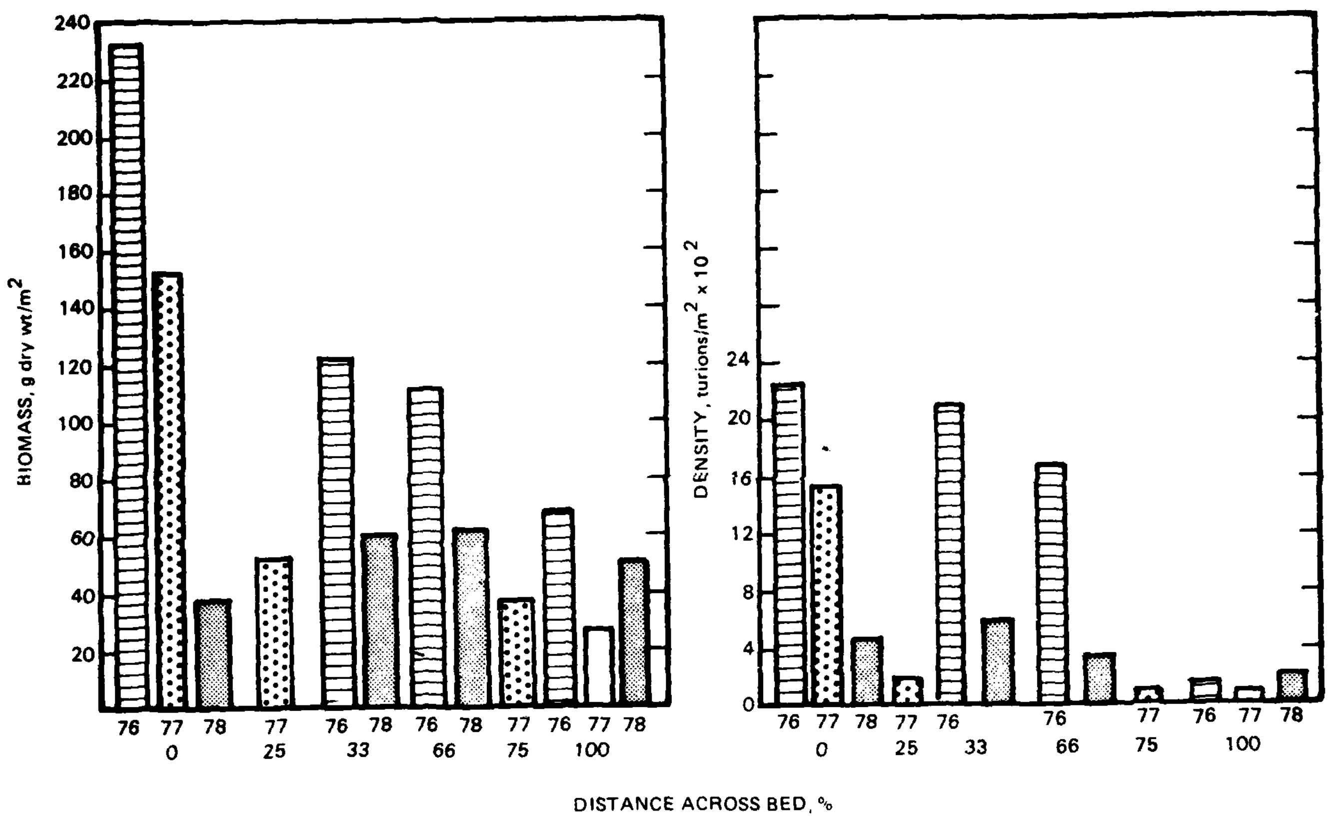

Figure C-2. Station E eelgrass bed density and biomass profiles (1976-1978).

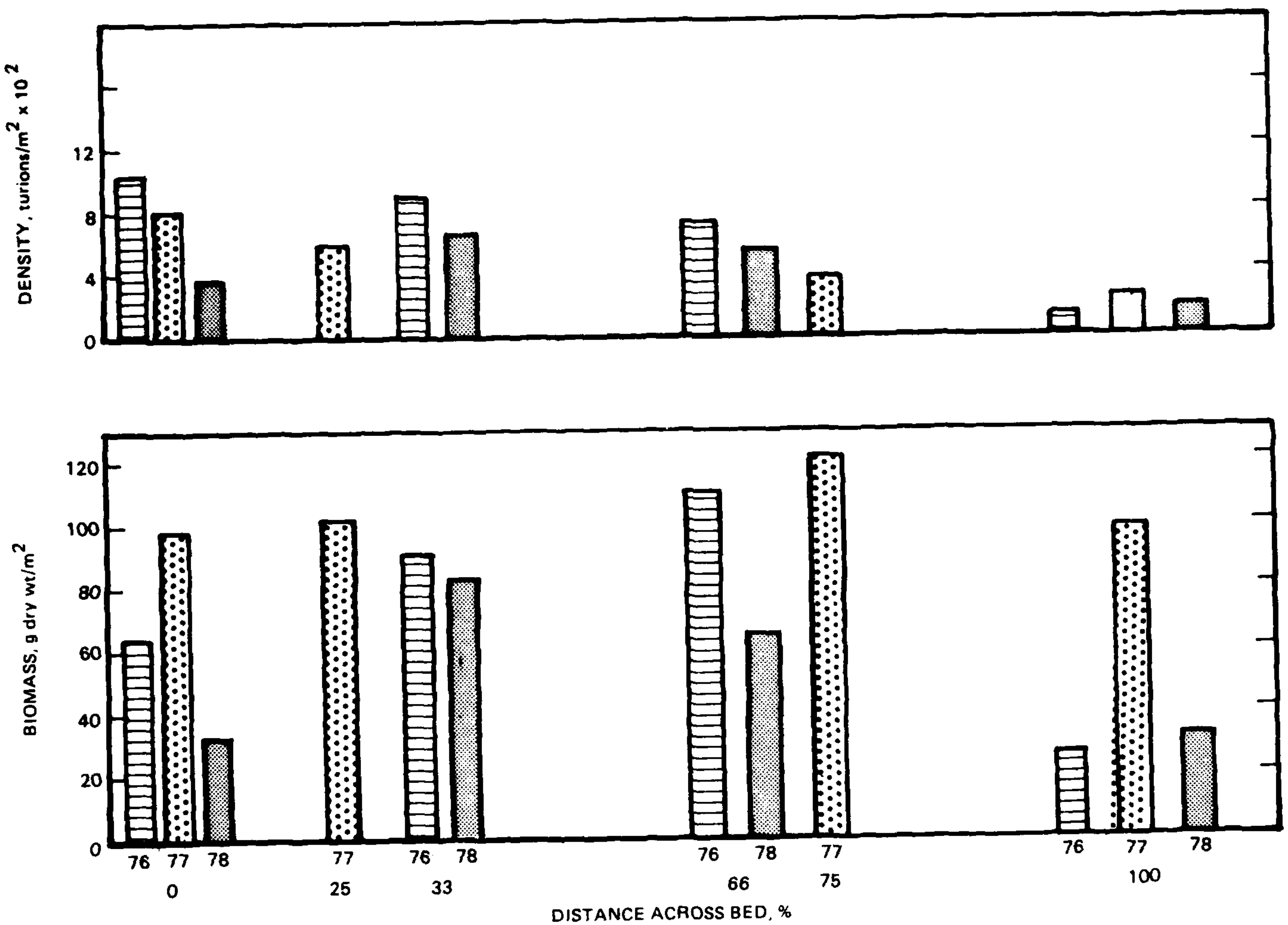

Figure C-3. Station K eelgrass bed density and biomass profiles (1976-1978).

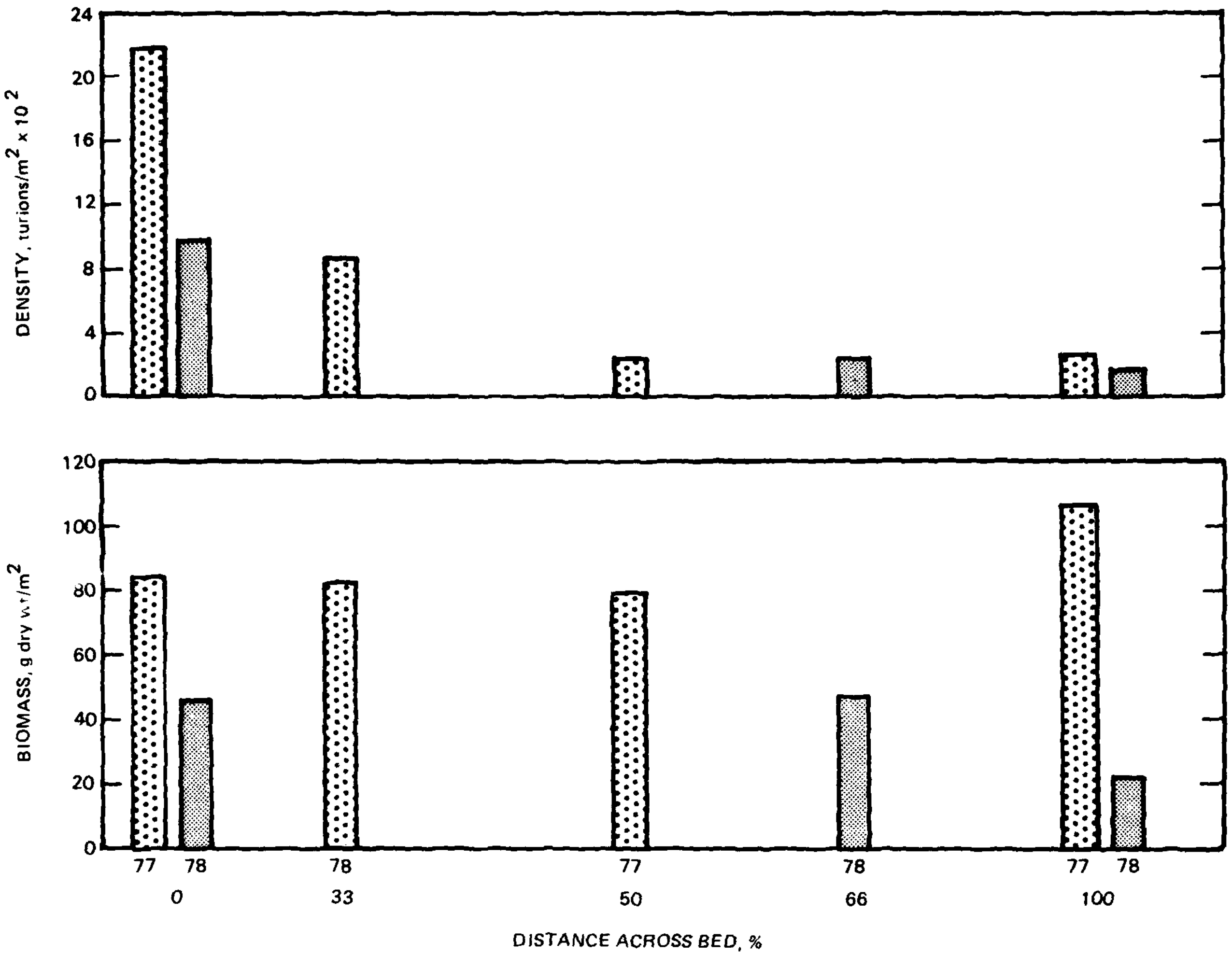

Figure C-4. Station L eelgrass bed density and biomass profiles (1977-1978).

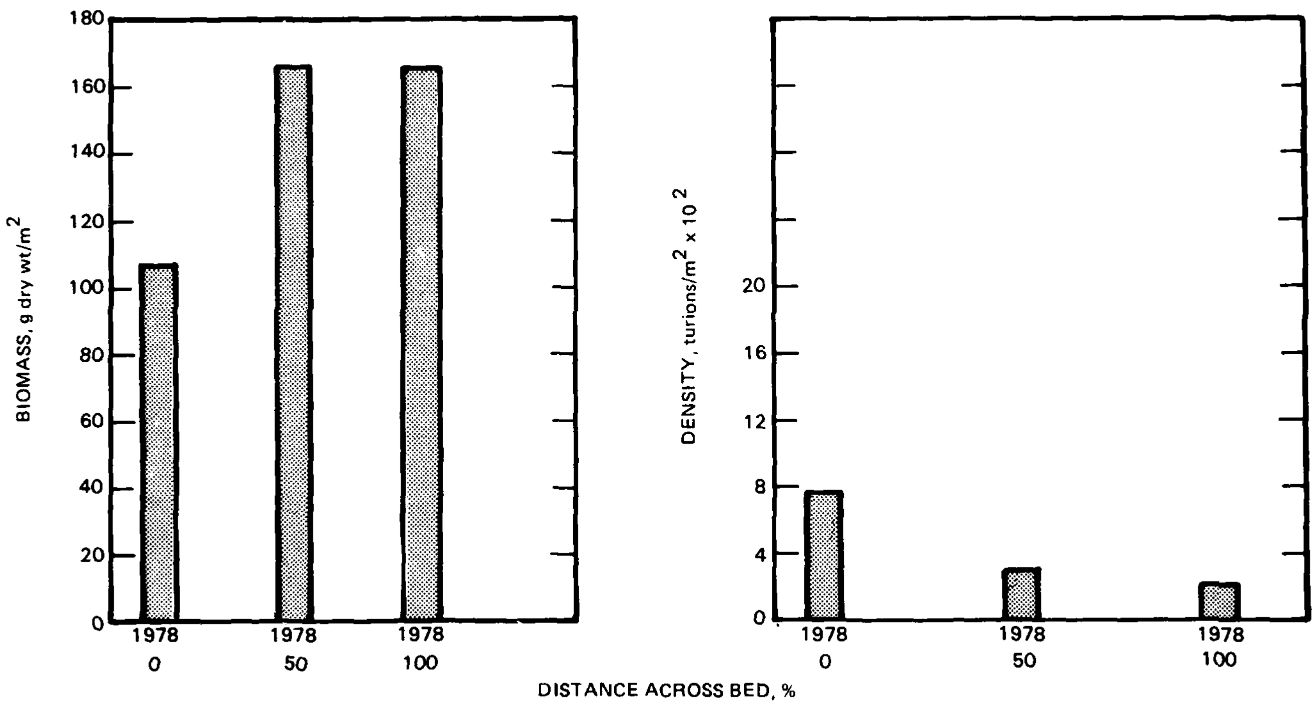

Figure C-5. Indian Island station I-C eelgrass bed density and biomass profile (1978).

APPENDIX D

Cumulative Checklist of
Marine Organisms Identified
During Three Biological Surveys
at Indian Island, Washington
(and Additions to the Cumulative Checklist
for SUBASE Bangor, Washington)

CHLOROPHYTA	*Monostroma* sp.
	Ulva lactuca
PHAEOPHYTA	*Costaria costata*
	Desmarestia ligulata
	D. viridis
	Laminaria saccharina
RHODOPHYTA	*Agardhiella tenera*
	Ceramium pacificum
	Gigartina papillata
	Polyneura latissima
	Porphyra perforata
	Rhodymenia callophyllidoides
SEAGRASSES	*Zostera marina*
CNIDARIA (=COELENTERATA)	*Metridium senile*
	Ptilosarcus guerneyi
	Anthopleura sp.
	Telia sp.
NEMATODA	*Philometra americana*
ANNELIDA	*Axiothella rubricinta*
	Eudistylia polymorpha
ARTHROPODA	
CRUSTACEA	
THORACEA	*Balanus glandula*
	B. nubilus
ISOPODA	*Idotea (=Pentidotea) resecata*
	I. wosnesenskii
	Exosphaeroma media
AMPHIPODA/GAMMARIDAE	Misc. unidentified
DECAPODA	*Spirontocaris prionota*
	S. sp.
	Cancer productus
	Hemigrapsus nudus
	Loxorhynchus crispatus
	Pugettia gracilis
	P. producta
	Telmessus cheiragonus
	Pagurus spp.

Table D-1. Cumulative checklist of marine organisms identified during biological surveys at Indian Island, Washington.

MOLLUSCA	
GASTROPODA	*Acmaea digitalis*
	Notoacmaea scutum
	Littorina scutulata
	L. sitkana
	Polinices lewisii
	Thais emarginata
	T. lamellosa
	Calliostoma lagatum
OPISTHOBRANCHIA	*Anisodoris nobilis*
	Hermissenda crassicornis
PELECYPODA	*Pododesumus cepio*
	Mytilus edulis
	Hinnites giganteus
	Macoma balthica
	M. secta
	M. irus (=inquinata)
	Tellina carpenteri
	Tresus capax
	Clinocardium nuttallii
	Prothothaca staminea
	Saxidomus giganteus
	Transennella tantilla
	Panope generosa
	Mya truncata
ECHINODERMATA	
ASTEROIDEA	*Evasterias troschelii*
	Pisaster brevispinus
	Crossaster papposus
	Solaster stimpsoni
	Pycnopodia helianthoides
OPHIUROIDEA	Misc. unidentified
ECHINOIDEA	*Strongylocentrotus drobachiensis*
HOLOTHUROIDEA	*Eupentacta quinquesemita*
	Stichopus californicus
UROCHORDATA	*Distaplia occidentalis*
	Boltenia villosa
	Pyura haustor
	Corella willmeriana

Table D-1. Continued

CHORDATA/PISCES	*Microgadus proximus* *Aulorhynchus flavidus* *Hexagrammos stelleri* *Blepsias chirrhosus* *Clinocottus acuticeps* *Leptocottus armatus* *Psychrolutes paradox* *Lumpenus sagitta* *Apodichthyes flavidus* *Pholis laeta* *Eumicrotremus orbis* *Liparis fucensis* *Lepidopsetta bilineata* *Parophrys vetulus* *Platichthys stellatus*

Table D-1. Continued

CHORDATA/PISCES	*Brachyistius frenatus* *Clinocottus embryum* *Hexagrammos stelleri* *Lumpenus sagitta* *Pholis leata*

Table D-2. Additions to the cumulative checklist of marine organisms for SUBASE Bangor, Washington.

AD-A086 462 NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA F/G 8/1
TRIDENT BIOLOGICAL SURVEYS: SUBASE BANGOR (JULY 1977 AND JUNE 1--ETC(U)
DEC 79 H W GOFORTH, T J PEELING, M H SALAZAR
UNCLASSIFIED NOSC/TR-513 NL

2 OF 2

AD
A08646?

SUPPLEMENTARY

INFORMATION

END
DATE
FILMED
10-80
DTIC

SUPPLEMENTARY

INFORMATION

AD-A086 462

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

7 AUGUST 1980

NOSC TECHNICAL REPORT 513
TRIDENT BIOLOGICAL SURVEYS: SUBASE Bangor (July 1977 and June 1978) and Indian Island Annex (January, May 1974 and June 1978),
H. W. Goforth, T. J. Peeling, M. H. Salazar and J. G. Grovhoug,
December 1979

LITERATURE CHANGE

1. Pages 3 and 4: Existing pages 3 and 4 to be replaced by attached pages.

SUMMARY

In July 1977 and June 1978, members of the Marine Sciences Division (Code 513) of the Naval Ocean Systems Center (NOSC) conducted two biological surveys of the Trident Submarine Support Facility, SUBASE Bangor, Washington. The primary objective was to collect selected biological data for an assessment of the marine environmental conditions during a period of facilities construction. The data from these surveys have been analyzed and compared with those from previous surveys and are presented in this report.

In January and May 1974 and June 1978, a series of biological surveys were conducted at Indian Island Annex, Washington for OICC Trident. The objective of the first two surveys was to collect seasonal biological baseline data from which the impact of proposed pier construction could be predicted. The third survey was designed to collect biological data for monitoring environmental conditions during on-going pier construction. The results and conclusions from these surveys are presented in a separate section of this report.

The major effort of these surveys was directed towards quantifying the abundance and distribution of commercially/recreationally important species of marine fishes and molluscs. Other biotic components of the Hood Canal ecosystem were surveyed according to their relative abundance and/or importance in the food web of other species. Detailed results and conclusions from these surveys are presented in the individual sections of this report. However, the general conclusion supported by the data collected from a total of eight surveys is that the marine life along the SUBASE shoreline appears to be unchanged by Trident construction. Any and all biotic fluctuations appear to be natural and are in synchronization with those observed at the off-base control stations. There have been no rare or endangered species, nor critical marine habitats affected by construction activities. Adverse impact has been limited to the biota physically disrupted by the mechanical process of pier construction.

Commercial clam densities, standing crop (biomass), recruitment and population distributions within the tidal zones have experienced only natural fluctuations. The total biomass of commercial clams has consistently been divided as follows: butter clams 70-90%, native littlenecks 10-30%, Japanese littlenecks 0-7%, basket cockles 0-5%, and soft-shell clams 0-5%. A few stations are found to support high densities of juvenile clams but few adults, suggesting that the environmental conditions responsible for heavy settlement (recruitment) may be unrelated to the conditions necessary for good growth and survival. On-base stations C, E, FA and Z were found to have clam densities of commercial levels which could support a well managed program of recreational harvesting. Stations CS, G and K have consistently had clam densities which are too low and patchy to be of any recreational value except for the more resolute clam digger.

Environmental conditions at several sites along SUBASE Bangor (i.e., stations C, E, K and Z) are quite conducive to good oyster settlement, growth and survival. Exceptionally good spawning conditions occurred in 1977 in Dabob Bay and Hood Canal which allowed for spatfall (recruitment) to reach commercial densities at stations C and Z. A detailed survey of the oyster bed at station C revealed a band of adult oysters 5.7 m wide and 560 m long having an average density of 36.8 oysters/m^2. Since approximately 92% of these oysters are of harvestable size, this station could easily support a controlled harvesting program. A detailed survey of the oyster bed at station Z will be conducted during survey IX (1979).

80 8 18 164

Byssal thread production tests with the bay mussel conducted in 1975, 1976, and 1977 found no differences among any of the survey stations before or during facilities construction and dredging. The summer rate of byssal thread production in Hood Canal, however, is approximately 50% higher than the summer rate in San Diego Bay and approximately 100% higher than the winter rate.

Marine fish collections during survey VII (1977) revealed a decline in both species composition and abundance compared with survey VI (1976). However collections during survey VIII (1978) revealed a complete return to the levels found in survey VI (1976). Fish collections in 1978 indicate a diverse species composition (20 species) and a relative abundance (428 individuals) that is consistent with reports of similar areas in Puget Sound. Stomach contents were typical for these species and revealed a diverse diet consistent with unstressed environmental conditions.

Eelgrass beds occurring along the Hood Canal shoreline showed large variations in standing crop (biomass) and turion (blade) density between and within stations, and between years. However, values for these measurements at stations A, E, G, K and L were average or slightly above average compared to other areas of Puget Sound.

Station FA supports only a small eelgrass bed and has a less than average turion density in the shallow portion of the bed. Stations E, K and L showed extremely large fluctuations in standing crop and density values, apparently a result of their greater exposure to natural siltation and erosion forces.

The three surveys conducted at the Indian Island Annex revealed the presence of marine invertebrate species typical for that area, but in very low abundance. Station I-B was found to be unsuitable for clams with a total of four non-commercial individuals collected during three surveys. Clam populations at station I-C were also depauperate and lower than any of the survey stations in Hood Canal. Subtidal geoduck and horseneck clams at station I-C were found to be low ($< 0.06/0.1\ m^2$) and comparable with values reported by Washington Department of Fisheries for central Puget Sound and Kilisut Spit. A substantial eelgrass bed is present at station I-C which is of average density and above average biomass. Any permanent loss of eelgrass as a result of pier construction at this station should be confined to the immediate vicinity of the pier. Fish populations sampled at Indian Island Annex contained species common to Admiralty Inlet without remarkable characteristics. Stomach contents contained food items typical for each species and representative of an unstressed environment. A cumulative species list for Indian Island Annex which contains many species common to Hood Canal is presented in Appendix D.